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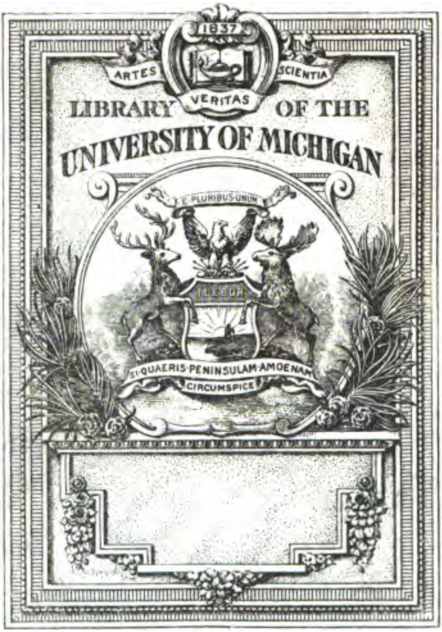

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A MANUAL OF LITHOLOGY.

BY

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PREFACE.

THE Course in Lithology at the Lehigh University is eminently practical. After a thorough grounding in Crystallography and Mineralogy, the student begins the study of rock-formation. Following the methods employed in the preliminary subjects, the theory and the definitions are first acquired, and afterwards a practical knowledge of the rocks is obtained by the examination of specimens. As the object of the course is to enable the student to classify at sight the more common species, only the macroscopic peculiarities are given. The aim of the writer has been to combine a thorough knowledge of the elementary portion of the subject with a brief account of the principal rocks and a ready method for their determination.

BETHLEHEM, July, 1886.

TABLE OF CONTENTS.

Introduction, ... ix

PART I.

PRELIMINARY DESCRIPTIONS.

CHAPTER I.—LITHOLOGY.

General Definitions, ... 1–8
  Rocks, ... 1
  Texture, ... 3
  Structure, ... 4
  Composition, etc., . . . 6

CHAPTER II.—MINERALOGY.

Physical Characters, ... 9
Description of the Principal Rock-forming Minerals, ... 10–39

PART II.

THE ROCKS.

CHAPTER I.—DIVISION OF THE SUBJECT.

General Definitions, ... 43–44

CHAPTER II.—PRIMARY ROCKS.

ACID VITREOUS CLASS, . . . 45–47

BASIC VITREOUS CLASS, . . 48

ACID CRYSTALLINE CLASS, . . . 48–62
  Crystalline-granular sub-class, . 49
  Crypto-crystalline sub-class, . . 53

INTERMEDIATE CRYSTALLINE CLASS, . 62–79
  Crystalline-granular sub-class, . 62
  Crypto-crystalline sub-class, . 69

BASIC CRYSTALLINE CLASS, . . . 79–92
  Crystalline-granular sub-class, . 79
  Crypto-crystalline sub-class, . . 87

CHAPTER III.—SEDIMENTARY ROCKS.

SEDIMENTARY CLASS, . . . 94–99
  Argillaceous Group, . . . 94
  Marl Group, ... 96
  Limestone Group, . . . 96

FRAGMENTAL CLASS, . . . 99–101

CHAPTER IV.—THE METAMORPHIC SCHISTS.

ACID SERIES, ... 102–106
  Feldspar Group, . . . 102
  Quartz Group, . . . 103

BASIC SERIES, ... 106–108
  Chlorite, Talc, and Hornblende Group, 106
  Argillaceous Group, . . . 108

CHAPTER V.—SPECIAL ROCKS.

SERPENTINE GROUP, ... 109
GARNET-OLIVINE GROUP, . . . 109–111
COAL GROUP, ... 111
GUANO GROUP, ... 112
IRON GROUP, ... 112
MINERAL GROUP, ... 112

PART III.

SCHEME FOR DETERMINING ROCKS.

CLASSIFICATION ACCORDING TO PHYSICAL, MINERALOGICAL AND CHEMICAL CHARACTERISTICS, ... 115–128

GENERAL INDEX, ... 129–135

INTRODUCTION.

As the science progresses, it becomes more and more evident that the earth's crust within a certain radius may contain the same elements, or even the same minerals, differently arranged and in varying proportions. These variations have resulted from the unequal amounts of heat, moisture, pressure, with other physical agencies, and the rapidity with which these amounts were applied or withdrawn; so that in the same mass, there will be found rocks of classes widely differing, according to the now-accepted laws of Lithology. From this it follows that a classification based upon the physical states of rock-masses will be the least artificial. Such has been the endeavor of the writer. The definitions given for each rock are to be taken as the mean of a series of states that may vary in all directions, and, if followed far enough in the same direction, will end in a rock of a different name and class. We can conceive the rocks of the earth to be related to one another by a variation in ingredients, in method of mixture, in conditions under which the mixture took place, or in the agencies to which the mass has been subjected since its aggrégation. The classes and divisions are arbitrary barriers separating a series of groups that may vary widely from the mean taken as a type, and which furnishes the definition. Rocks of the same name from different localities may appear to have nothing in common, and only a close study will establish a similarity. If the student will bear in mind these facts as he studies the subject, he will find a solution to many puzzling questions, but, should he look for rocks that always follow identically the definitions given, he will continually meet with disappointment. The definitions are therefore elastic enough to take in all the varieties of a species, and these variations, when of sufficient importance, are noted.

Dana and Brush are taken as the standards in mineralogy and blowpiping.

LITHOLOGY.

CHAPTER I.

GENERAL DEFINITIONS.

LITHOLOGY is that branch of Geology which treats of the materials composing the earth's crust, under the name of *rocks*, though the idea of a solid state is not necessarily implied.

ROCKS are mineral aggregates, and may be either *simple*, when formed essentially of one mineral, or *composite*, when made up of two or more different ones. Care must be taken to note only the *essential* ingredients in determining the name of the rock, and to exclude those accessories which are generally local in their occurrence or inconsiderable in quantity, but which sometimes impart a special character to it, by placing it in a variety of the original species. A mineral is an *essential*, when its absence would so materially alter the character of a rock as to throw it into another species. A rock, however, may contain the same mineral as an *essential* and as *accessory*. Quartz is an essential in mica schist. Mica schists are frequently found crossed by quartz veins due to fracture, and this intrusive quartz is entirely an accessory.

Rocks may be classified in various ways, depending upon the basis established. This may be chemical, geological or physical. The methods in common use are founded upon a cross of one or more of the above, and are changed continually with new discoveries. The one here employed depends upon the physical properties of rock masses known as texture, structure, composition, hardness, weathering, color and luster, feel and smell, specific gravity and magnetism; and their mineralogical composition.

TEXTURE refers to the shape, size, and mode of adhesion of the individual mineral particles.

I.—When the particles can be recognized by the naked eye. The varieties are,

CRYSTALLINE. Composed of particles *crystallized into one another.* When they are of large size, the texture is *coarse crystalline,* as in some granites and hypersthenes.

When of moderate and nearly uniform size, it is styled *crystalline granular* or *granitoid,* as in granites in general.

The terms *fine-crystalline, micro-crystalline* and *crypto-crystalline* are also used to denote varying degrees of fineness in the component parts.

[NOTE.—In addition to the crystals in crystalline rocks, there is sometimes a pasty matrix, in which the crystals seems to be imbedded, called "ground-mass," when composed of minute crystals, as shown by the microscope, or "magma," when of homogeneous or amorphous matter. Examples of these are seen in "porphyries."]

GRANULAR. Composed of grains or irregular crystals *mechanically cemented together*, as in some semi-metamorphic granites, marbles, etc.

Clastic or Fragmental. Composed of fragments more or less worn. The varieties are named from their size and shape; *e. g.*, *agglomerated* when composed of large blocks roughly thrown together. When the fragments are angular, the texture is styled *brecciated;* when rounded *conglomerated.*

Arenaceous is a general term for a sandy composition, and *gritty* a special one when the grains are sharp and of good size. *Argillaceous* denotes a muddy, clayey consistency, and *crypto-clastic* bears the same relation to the general term, that crypto-crystalline does to crystalline. All the above varieties pass by degrees into the state

II.—When the particles cannot be distinguished by the naked eye.

A.—When they are fused together.

Vitreous or *Glassy.* Having a texture and luster like glass, as in obsidian.

Resinous. With a similar texture and a resinous luster, as in pitchstone.

Horny, flinty. Having a homogeneous, crypto-crystalline texture and a waxy luster, as in jasper and flint.

Stony. Having a texture similar to the above, and wanting in luster. This is usually the result of what is called "devitrification," and is the conversion of the vitreous into a crystalline texture.

B.—When they adhere loosely without fusion.

Compact. Having a dull, firm, homogeneous texture.

Earthy. Consisting of loose, friable particles.

Plastic, *pulverulent* and *incoherent* are terms of which the meaning is well known.

STRUCTURE. The varieties of structure are designated by common adjectives applied to rocks in which the special structure occurs. While *texture* refers to the arrangement of the minute particles, *structure* refers to the state of aggregation of the rock as a mass.

The following varieties are especially worthy of note:

SHALY. With the particles arranged in layers, beds, or strata, parallel to one another. Such a structure is also styled *stratified* and, when the strata are fine, *laminated.*

SCHISTOSE. With the layers wavy and generally parallel. Frequently, caused by the parallel arrangement of minerals eminently cleavable in one direction, as mica, talc, chlorite, hornblende. Such a structure is also styled *foliated.*

SLATY. When the texture is fine and the rock shows a tendency to cleave in any given direction, such a structure is called *slaty* or *fissile*. In case the cleavage be parallel to the bedding it would be due to lamination; if at an angle to the bedding it would be due to pressure normal to the cleavage plane. A slaty cleavage is a characteristic of rocks of fine texture, and is seldom found in coarse or gritty rocks. In general we may say that the texture of the schists is coarser than that of shales and slates, and "when we wish to be precise, we speak of the '*foliation of schists*,' the '*cleavage of slate*,' and the '*lamination of shale.*'" (*Jukes.*)

MASSIVE. Having no arrangement in strata. This includes all crystalline rocks which have solidified from a plastic state.

CELLULAR. A term applied to rocks containing cavities more or less rounded; the result of gas bubbles developed when the rock was in a soft state, either at the time of its origin, or at a subsequent period. The shape of the cavities is generally irregular; but sometimes regularly spherical, pear-shaped, and lenticular. Occasionally they show evidences of having been stretched in one or more directions. These varieties of shape can be explained by the circumstances under which the mass solidified; whether it was in a state of rest or one of motion and, if the latter, whether the motion was constant or irregular. This structure is most commonly met with in fine grained volcanic rocks that have cooled quickly. If these are *few* and *isolated* the rock is styled *vescicular:* if they occupy an equal space with the solid part it is called *scoriaceous* or slag-like, and, if the cavities predominate, *pumiceous*.

AMYGDALOIDAL. When the preceding cavities are wholly or partially filled with new mineral substance, usually zeolites, calcite, quartz or chalcedony. The filling of these cavities has been a slow process subsequent to the formation of the rock, and the material has generally been derived from the rock itself by a species of exfiltration.

POROUS. Penetrated by irregular and often angular cavities, due to the removal of some of the minerals, or to the interstices left during the formation of the rock: *not due to gas*.

CONCRETIONARY. Including or consisting of mineral matter which has collected about some nucleus and formed an irregularly shaped lump. When the entire mass is composed of fine globules, it is styled *oölitic*. This structure is found only in limestones and ironstones. When the globules have the size and shape of peas, it becomes *pisolitic*.

SPHERULITIC OR GLOBULIFEROUS. A structure similar to the oölitic which occurs in some felsitic igneous rocks, where it sometimes is one of the stages of devitrification. It is found in basalt, dolerite, phonolite and obsidian. When it is accompanied by minute rectilinear fissures traversing the mass, and between which this structure occurs, it is called *perlitic*. The texture of these globules may be crystalline or colloid: if the former it is frequently fibrous and divergent.

PORPHYRITIC. Composed of distinct crystals or crystalline particles distributed through an otherwise compact magma or finely-crystalline ground mass. Depending upon the *texture of the matrix* we distinguish,

Pophyries, when the matrix is compact; and when *glassy*, the rocks are called *vitrophyres;* when dull and felsitic, *felsophyres*. When the matrix is generally finely crystalline, *granophyres*. (Cf. *Vogelgesang*.)

Porphyritic is an adjective applied to all rocks not included under the above heads, *e. g.*, mica schists, gneisses, etc., containing crystals.

COMPOSITION. By this is meant the general chemical or mineralogical nature of a rock, and the terms employed are derived from the names of minerals, and generally explain themselves, *e. g.*,

Calcareous, containing lime, generally the carbonate.

Felsitic, having some feldspar as a principal ingredient.

Arenaceous, composed of sand-like grains.

Argillaceous, containing clayey matter.

Ferruginous, cemented together by, or containing oxide or carbonate of iron.

Siliceous, *Quartzose*, containing silica. The former in a colloid, the latter in a crystalline condition.

HARDNESS. This refers to the original state of the rock and not the hardness after weathering. In felsitic rocks, exposure will decrease their hardness; in sinters, it will increase it. The same scale is adopted that obtains in mineralogy.

FRACTURE. This depends upon the texture, and is the surface produced by splitting or breaking the rock. The varieties are,

Conchoidal. When the broken surface exhibits shell-like forms, convex or concave, as seen in obsidian, artificial glass, etc.

Splintery. When the surface is covered with partially separated splinters in irregular fibers.

Smooth. When, without being plane, the surface presents no irregularities.

Foliated, *laminated*, *slaty*, can be inferred from previous definitions.

COLOR. This varies in the same rock according to whether the surface has been exposed so as to be weathered, or is from a fresh fracture. Yet certain rocks are characterized by one color when fresh and by a second when weathered, so that the variation in color between the two surfaces affords a means of determining the rock, as in phonolite. In general it may be stated that

White shows an absence of iron or other heavy metallic oxides.

Black indicates carbon, magnetite, or an iron silicate.

Dull yellow is generally due to hydrated oxide of iron, or sulphur:

Bright yellow, to pyrites.

Brown indicates lignite, and is also due to the hydration of iron and manganese minerals.

Red is due to anhydrous ferric oxide.

Green is found in rocks poor in silica and free quartz. If schistose, the color is due to talc, chlorite, or serpentine; if massive and crystalline, to the formation of chlorite. The decomposition of copper ore also forms green crusts or stains.

Luster, *Feel*, *Smell*, *Specific Gravity*, and other properties not mentioned are taken as defined in Dana's Mineralogy.

CHAPTER II.

MINERALOGY.

As constituents of rocks, minerals occur under four conditions, visible to the naked eye, according to the circumstances under which they were formed.

1. *Crystalline.*

a. More or less regularly defined crystals.

b. Amorphous granules or aggregations. This condition may be the result of igneous fusion or aqueous solution.

2. *Glassy* or *vitreous.* As a natural glass, usually including crystals, or crystallites, or both. The result of fusion.

3. *Colloid.* As a jelly-like, though stony, substance like chalcedony—the result of aqueous solution.

4. *Amorphous.* Having neither crystalline structure nor form, and occurring in indefinite masses, granules, streaks, tufts, stainings, or other irregular states.

In regard to the frequency with which minerals are found in rocks, they may be divided into two groups,

a. Those of common occurrence, as quartz, the feldspars, the micas, hornblende, pyroxene, calcite and dolomite.

b. Those of frequent occurrence, as hypersthene, chlorite, talc, serpentine, sodalite, haüyne, leucite, nosite, nepheline, olivene, garnet, tourmaline, epidote, topaz, zircon, gypsum, the coals, zeolites, iron ores and a few sulphurets.

Minerals of common occurrence.

1. QUARTZ. Hexagonal. It occurs:

1.—Crystalline.

a. As an independent rock;

b. As an essential ingredient in many crystalline rocks and especially in the crystalline schists; *e.g.*, granite, gneiss, etc.;

c. As principal ingredient in many clastic rocks (sandstones, conglomerates), and as sand and gravel.

2.—Non-crystalline.

a. As agate, jasper, flint, and chert.

H. 7: Gr. 2.5–2.8, average 2.6: colorless and limpid, or variously colored: Comp. SiO_2: luster vitreous, sometimes resinous or waxy, especially on the surface of fractures.

Bp. (crystalline variety), alone, unaltered: with soda dissolves with effervescence: untouched by microcosmic salt. (Crypto-crystalline variety), with borax dissolves to a clear glass.

Chem. (Crystalline), soluble in HF alone. (Crypto-crystalline), slightly acted upon by caustic alkalis.

Weathering. (Crystalline), unchanged; though crystals have been found with corroded edges. (Crypto-crystalline), forms a white crust, as in flints.

Quartz is associated with almost every other mineral; but it is more commonly found with orthoclase and the acid silicates. It frequently occurs with tourmaline, rutile, cassiterite and topaz. It is found more frequently with hornblende than pyroxene; with muscovite than biotite.

THE FELDSPARS.

This series is the next in importance after quartz, as its members constitute by far the larger part of the rocks of igneous origin. It is divided into the mono- and triclinic groups.

Monoclinic Group. From its principal type this is frequently called the *Orthoclastic* group: It contains orthoclase and sanidine: its two most perfect cleavage planes meet at an angle of 90°.

Triclinic Group. This is also styled the *Plagioclastic* group from the fact that the angle formed by its two most perfect cleavage planes is less than 90°. Its members are anorthite, labradorite, andesite, oligoclase, albite, and microcline.

Orthoclastic Feldspars.

2. ORTHOCLASE. Monoclinic.

H. 6: Gr. 2.5–2.6; transparent, translucent; colorless, more frequently greenish-white or flesh-red: luster, vitreous, sometimes pearly on cleavages.

Bp. Fus. 5, on thin edges to a dull porous glass: with microcosmic salt, soluble with difficulty, leaving a skeleton of silica; with cobalt, fused edges are colored blue.

Chem. Untouched by acids; decomposed by fusion with alkaline carbonates.

Weathering. Decomposes with comparative rapidity, by removal of the alkali, and changes to kaolin more readily than albite; but less so than labradorite, anorthite and oligoclase.

It is an essential in granite, syenite, felsite and gneiss; is frequently associated with quartz, oligoclase, hornblende and mica; is seldom found with pyroxene. It twins according to the Carlsbad and Baveno types. The suture of the former is easily detected, as the two portions, when fractured, show differences in color and luster. It often shows striations in some red varieties from Upper Egypt and elsewhere, from the inter-crystallization of laminae of albite, and these must not be confounded with the similar markings, due to twinning, in the plagioclase group.

3. SANIDINE. Monoclinic.

Like orthoclase, except that it contains more soda. The crystals are generally tabular (whence the name); luster, vitreous; color, grayish, yellowish-white; occurs only in genuine volcanic rocks, as phonolite, trachyte, pitchstone, and obsidian; presents a creviced, fissured appearance, as if the crystals had formed before the body of the mass had ceased to flow.

Plagioclastic Feldspars.

The members of this group may be considered as mixtures, in various proportions, of albite and anorthite. They occur,

a. As well-developed crystals;

b. As crystalline grains;

c. As crypto-crystalline paste.

On a fresh fracture, when the light falls somewhat obliquely on the basal cleavage plane, they frequently show a striated appearance, from the repeated twinning of thin laminae; while these striae are indications of this group, their absence does not necessarily place the specimen in the former group. The more acid varieties (albite and oligoclase), occur with orthoclase as essentials in granite; while the basic members (anorthite and labradorite), are generally absent when free silica, or acid silicates, are present. Their differences can readily be seen from the table, pp. 14–15.

General Remarks.—An abundance of calcite or calcareous zeolites, as chabasite, phillipsite, stilbite, etc., is an indication of a lime feldspar, and the above are due to its decomposition. We frequently find together orthoclase and oligoclase; orthoclase, oligoclase and hornblende; labradorite and pyroxene; labradorite and hypersthene: we seldom find together the alkali feldspars and the calcareous feldspars; orthoclase and pyroxene; oligoclase and leucite; oligoclase and nepheline; labradorite and hornblende; anorthite or labradorite and quartz or leucite. As noted above, the feldspars weather quite differently, and can be arranged in the following order, beginning with the most easily decomposed: labradorite, oligoclase, orthoclase, albite. If we have two feldspars in a rock and one be weathered, we can determine its species with a high degree of probability if we can recognize the unweathered species.

THE MICAS.

Lepidolite and muscovite are the acid micas; the others are more basic. The characteristics are shown by the following table, where they are arranged according to their acidity:

Damourite, *margarodite* and *sericite*, may be taken as hydration products of muscovite. They contain 3–5.25 per cent. of water.

	H.	*Gr.*	*Luster.*	*Color.*	*Optical Characters.*	*Texture.*
4. Anorthite.	6.—7.	2.7	Vitreous on a fracture; pearly on a cleavage surface; greasy when imbedded in rocks.	Grayish-white, reddish.	Transparent, to translucent.	Granular, coarse lamellar.
5. Labradorite.	6.	2.7	Pearly on a basal cleavage; elsewhere sub-pearly.	White, gray, brown, greenish, bluish.	Transparent, on thin edges; sub-translucent.	Coarse granular, *massive, cryptocrystalline.
6. Andesite.	5.—6.	2.67	Sub-vitreous to pearly, greasy.	White, gray, greenish, yellowish, flesh-red.	Transparent to translucent.	Coarse granular, massive.
7. Oligoclase.	6.	2.67	Vitreo-pearly to vitreous, resinous, waxy, greasy.	White, grayish, greenish. reddish.	Transparent sub-translucent.	Massive.
8. Albite.	6.	2.6	Pearly on a cleavage face; vitreous on a fracture.	Bluish, gray, reddish, greenish, green.	Same.	Coarse granular, coarse lamellar, fine granular.
9. Microcline.	6.	2.54	Opalescent.	Whitish, grayish, reddish.		In cleavable masses.

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* See Saussurite, p. 34.

Bp.		*Chemical Reactions.*	*Cleavage.*	*Weathering.*	*Remarks.*
Alone.	*With Borax.*				
4.5 to a colorless glass.		Decomp. by HCl with sep. of gelat. silica.	85° 50′		An essential in orbicular diorite and Vesuvian lavas; when imbedded in the rocks, the crystals have a greasy luster; when in druses, they are limpid and vitreous; it seldom occurs with quartz and leucite.
3.5 to a colorless glass.		When fresh is with diff. sol. in HCl and leaves part undecomp.; when powdered, completely soluble in hot HCl; when weathered, acts like anorthite.	86° 40′	Easily.	An essential in augitic rocks (basalt, dolerite); is abundantly developed in the archaean rocks of Canada; occurs chiefly in rocks containing little or no quartz; seldom in rocks containing hornblende or leucite; weathers more readily than orthoclase or albite.
5. on thin splinters	To a clear glass.	Soluble in HF; imperfectly so in other acids.	87°—88°	Easily, turns to Kaolin.	May be taken as an oligoclase rich in lime; essential in many trachytic rocks of the Andes and in some syenites.
3.5 to a colorless glass or colorless enamel.		Scarcely affected.	86° 10′	Easily.	Essential in diorite and, with orthoclase, is found in some granites, syenites, and trachytes; is seldom found with leucite and nepheline; weathers more readily than orthoclase and albite.
4. to a colorless glass.		Untouched.	86° 24′	The least easily of all the Feldspars.	Found in many diorites and granites; untwinned crystals are rare; is the least readily decomposed of all the feldspars by weathering.
5. on thin splinters		Untouched.	89° 38′		Occurs in miascite.

	H.	*Gr.*	*System.*	*Luster.*	*Color.*
10. Lepidolite.	2.5—4.	2.84—3	Orthorhombic.	Pearly.	Rose-red, violet-gray, lilac, yellowish, grayish, white.
11. Muscovite.	2—2.5.	2.75—3.1	Monoclinic.	Metallic-pearly.	White, green, brown, yellow, rarely rose.
12. Phlogopite.	2.5—3.	2.78—2.85	Orthorhombic.	Pearly to sub-metallic.	Yellowish-brown, brownish-red with copper-like reflections.
13. Lepidomelane.	3.	3	Hexagonal.	Adamantine to vitreo-pearly.	Black, leek-green reflection.
14. Biotite.	2.5—3.	2.7—3.1	Hexagonal.	Splendent; pearly on cleavage; sub-metallic when black; lateral surfaces vitreous when smooth.	Green to black; when thin, green to blood-red; rarely white.

Physical Characters.	*Optic-axial angle.*	*B.B.*	*Chem.*	*Remarks.*
	Sometimes 45°—60°; 70°—78°	Fuses 2—2.5 to white or grayish glass and colors the flame red; $H_2O + F$ in closed tube.	Attacked, but not decomposed, by acids; after fusion, gelatinizes with HCl.	Essential in greisen; occurs in granite veins and gneiss.
Thin laminae elastic and very tough.	44°—78°	Fuses 5.7 to a gray or yellow glass; in closed tube like 10.	Not decomposed by acids; decomposed by fusion with alkaline carbonates.	Is the most common of all the micas; occurs in granite, gneiss and mica schist; occasionally in trachyte, basalt, etc., in the older plutonic and metamorphic rocks.
Thin laminae tough and elastic.	4°—20°; rarely less than 5°	Whitens and fuses on thin edges; in closed tube like 10.	Completely decomposed by H_2SO_4, leaving silica in thin scales.	Is characteristic of serpentine and crystalline limestone.
Laminae brittle and little elastic	Unaxial; or with a very small angle.	Becomes brown at red heat and fuses to black, magnetic globule.	Easily decomposed by HCl, leaving silica in scales.	
	Seldom 1°; never exceeds 5°	Same as 13.		Occurs in igneous rocks of all ages and in the crystalline schists. Essential in the mica-traps.

PYROXENE GROUP.

All the minerals of this group crystallize in the monoclinic system and are bi-silicates of different protoxides. These are lime, magnesia, iron, manganese, and sometimes potash and soda. Sometimes these are replaced by sesquioxides of alumina, iron and manganese. Chemically, the pyroxenes may be divided into those which are poor in, and those containing from three to over nine per cent. of alumina.

Asbestus is in some cases a fibrous form of augite, but most asbestus is hornblendic in its affinities.

AMPHIBOLE GROUP.

The minerals of this group closely resemble pyroxene in chemical composition, while they also crystallize in the same system (monoclinic). Their chemical composition is similar to the pyroxenes. They can be divided into an aluminous and a non-aluminous group (the former containing, sometimes, 15 per cent. of alumina). The alteration products of the two groups are also very similar.

The minerals of the amphibole group frequently show a tendency to develop long blade-like crystals. One of the principal varieties, actinolite, shows this tendency in a very marked manner, the crystals arranging themselves in radiate groups. Actinolite is a magnesia-lime-iron amphibole; it is usually of a dark green color.

Tremolite is a magnesia-lime amphibole; in color it is generally white or grayish. Nephrite or jade is in part a tough, compact, fine-grained tremolite, having a tinge of green or blue, and breaking with a splintery fracture and glistening luster. It usually occurs associated with talcose or magnesian rocks.

Asbestus or amianthus is a fibrous variety of hornblende occurring in white silky fibers, which are matted together but are easily separable.

Ordinary hornblende, its variety pargasite, smaragdite,* which is a foliated grass-green form of hornblende, somewhat resembling diallage in appearance, and gamsigradite, which is velvet-black, are varieties of the aluminous sub-group of amphibole.

COMPARISON OF THE TWO GROUPS.

The angle formed by the oblique rhombic prism in augite is 87° 5′. The corresponding angle in hornblende crystals is 124° 30′. This great discrepancy in their angular measurements, serves to distinguish the minerals of the one species from those of the other. The specific gravity of hornblende is about nine-tenths that of pyroxene. Color also affords no safe means of discriminating between pyroxene and amphibole, since the members of both groups exhibit greenish and brownish tints. The augites and hornblendes which occur in basalt, are mostly brownish in color. The hornblende in syenite is also generally brown, but that which occurs in phonolite is mostly of a greenish tint, while the augite in leucite-lavas is, as a a rule, also green. Both hornblende and augite sometimes occur together in the same rock ; but as a rule the former mineral is found in those rocks which contain a large percentage of silica, the associated minerals being usually quartz, orthoclase, albite, and potash micas, while augite is generally found in rocks of a basic character containing magnesian micas, triclinic felspars, and with little or no free silica; pistacite and pyrites are most frequent accessories of hornblendic rocks; leucite and olivene of pyroxenic rocks; amygdaloidal minerals containing lime are also more characteristic of pyroxenic than of hornblendic rocks. Augite and its variety, diallage, sometimes occur together in the same rock, and in such cases the petrologist often has difficulty in the precise determination of the pyroxenic constituents.

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* Smaragdite is described by some authorities as an alternate combination of crystalline laminae of hornblende and pyroxene.

For the purposes of comparison, the following three minerals will be discussed out of the regular order:

HYPERSTHENE.

Orthorhombic system. Usually occurs, in rocks, in a crystalline condition or in granules, but seldom in actual crystals. The mineral shows a strongly marked cleavage parallel to the brachypinakoid. The color is black, grayish, brownish-green, or pinchbeck-brown, and presents in certain directions a glistening appearance or bronze-like luster.

Before the blowpipe it fuses to a black enamel, and, on charcoal, to a magnetic mass. It is essential in hyperite.

ENSTATITE.

Orthorhombic system. Cleavage parallel to the faces of rhombic prism. The cleavage planes make, by their intersection, angles of 88° and 92°.

The cleavage surfaces sometimes have a fibrous appearance, and usually a rather pearly or vitreous luster, while in some varieties it is metalloidal. In color the mineral ranges from grayish- or yellowish-white to green and brown. It occurs massive and lamellar as well as crystallized. It is almost infusible before the blowpipe, the edges of only very thin splinters becoming rounded. It is insoluble in hydrochloric acid. Enstatite becomes altered to schiller-spar or bastite, talc, etc., and occurs in lherzolite and certain gabbros.

BRONZITE.

It is very difficultly fusible, the edges only of very thin splinters becoming rounded before the blowpipe. It is insoluble in acids. The color is more brown than enstatite; the luster more submetallic or bronze-like (hence the name).

	H.	*Gr.*	*Angle of Prism.*	*Luster.*	*Color.*
15. Pyroxene.	5.—6.	3.25—3.5	87°5′—92°55′	Vitreous to resinous; sometimes pearly.	Deep-green to greenish-black.
a. Diallage.	4.	3.3		Pearly; metalloidal or brassy.	Grass-green.
b. Omphacite.	5.—6.	3.2—3.3		Vitreous.	Grass-green; leek-green.
16. Hornblende.	5.—6.	3.—3.4	124°30′	Vitreous to pearly, and when fibrous, silky.	Grayish-green to black.
a. Tremolite.	5.—6.5	2.9—3.1			White to dark-gray.
b. Nephrite.	6.—6.5	3.		Glistening.	Like (*a*) with a tinge of green or blue.
c. Actinolite.	5.5	3.—3.2		Pearly to vitreous.	Bright-green; grayish-green.
d. Gamsigradite.	7.	3.12	124°26′		Velvet-black.
e. Smaragdite.	5.	3.	124°30′		Grass-green.
17. Hypersthene.	5.—6.	3.39	86°30′	Pearly to metalloidal.	Dark brownish-green; grayish-black; pinchbeck brown.
18. Enstatite and Bronzite.	5.5	3.19	87°	Pearly to vitreous; metalloidal in bronzite.	Grayish-green; yellowish; olive-green; brown.

Texture and Structure.	*B. B.*	*Chem.*	*Remarks.*
Crystals thick and stout; granular; fibrous.	Fusible 3.5—6.	Unacted upon by acids.	Seldom found with free quartz, acid feldspars or potash micas; occurs with magnesia micas and basic feldspars; not found in the metamorphic crystalline schists; essential in dolerite, diabase and basalt.
Thin foliated.	Fusible 6.		Essential in gabbro; found in serpentine.
Massive; granular.			Generally associated with garnet; occurs in eklogite.
Massive; granular; columnar; fibrous.	Fusible 3.5—6.		Occurs with free quartz, acid feldspar or potash micas, and in the metamorphic crystalline schists.
Crystals long-bladed, and short and stout.	Fusible 3.5 to a white glass.		Occurs in limestone and dolomite.
Tough, compact; breaking with a splintery fracture.			Occurs in talcose schists and granular limestone.
Short and long-bladed crystals.	Fuses 5. to a black or green glass.		Is a tremolite with an admixture of iron. Occurs in talcose and chloritic rocks and forms a schistose rock alone.
Short and stout crystals.	Fuses 6.		Essential in timazite.
Crystalline; slaty; fibrous.			Occurs in gabbro, euphotide, and eklogite.
Crystals; foliated; massive.	Fuses to a black enamel, and on charcoal gives a magnetic mass.	Partially decomposed by HCl.	Essential in hyperite; occurs in gabbro.
Fibrous appearance on cleavages; also massive, lamellar.	Fusible 6; only slightly rounded on thin edges.	Insoluble in HCl.	Essential in lherzolite.

CALCITE: DOLOMITE.

	H.	Gr.	Luster.	Color.		B.B.	Chem.	Remarks.
19. Calcite.	2.5—3.5	2.5—2.8	Vitreous; earthy.	White: variously colored; black.	Transparent; opaque.	Infusible.	Soluble in cold HCl.	Occurs as limestone; oölite; marble; chalk; coral.
20. Dolomite.	3.5—4	2.8—2.9	Vitreous; pearly.		Translucent.		Soluble in hot HCl when powdered; not soluble in cold, diluted HCl.	More frequently associated with serpentine and other magnesian rocks, than limestone.

Next to quartz, calcite is the most common of the minerals and forms nearly as large a proportion of the crust of the earth.

Pure calcite is seldom found in nature. Limestone generally contains admixtures of dolomite, clay, silica, iron oxides and other minerals.

Dolomite as a rock is equally impure. It occurs almost as extensively as calcite. It is probable that it had a similar origin, but some authorities consider it a transmutation of limestone by solutions of magnesia.

The minerals just described form nearly all the rocks of the world; those which follow are generally accessory, but may sometimes become so predominant as to be essential.

THE MARGAROPHYLLITES.

These occur, principally, in metamorphic rocks, though all may be found as accessories in primary rocks, or are the results of weathering.

	H.	*Gr.*	*Luster.*	*Color.*	*Physical Characters.*	*B.B.*	*Chem.*	*Remarks.*
21. Chlorite.	2—2.5	2.65—2.78	On cleavage face, pearly.	Grass-green to olive-green; also rose-red.	Flexible and somewhat elastic.	Gives water; fuses with difficulty to a grayish-yellow enamel.	Decomposed by HCl; completely by H_2SO_4.	Essential in chlorite schist; occurs in diabase.
22. Talc.	1—1.5	2.56—2.8	Pearly.	Apple-green to white; darker and brownish when impure.	Thin laminae flexible, but not elastic.	Gives a little water; in the forceps, whitens, exfoliates, and fuses with difficulty to a white enamel; moistened with cobalt solution, assumes on ignition a pale red color.	Not decomposed by acids.	Essential in talc-schist.
a. Steatite.	1—2.5			Brownish; blackish green; reddish.			Decomposed with boiling H_2SO_4.	
23. Pyrophyllite.	1—2	2.75—2.92	Of folia, pearly; of massive kinds, glistening.	White; apple-green; yellowish to ochre-yellow.		Gives water; fuses with difficulty on thin edges; heated with cobalt, gives a blue color.		Occurs in some schists.
24. Serpentine.	2.5—4; rarely 5.5	2.5—2.65	Sub-resinous to greasy; wax-like; feeble.	Leek-green; blackish-green; oil-green; brownish-red; brownish-yellow.	Some varieties have flexible fibers, some elastic.	Loses on ignition 12-13 percent. of water; fusible 6; soluble in microcosmic salt with effervescence.	Decomposed by HCl without gelatinizing; also by H_2SO_4.	Generally supposed to be of metamorphic origin; occurs as an independent rock.

NEPHELINE—LEUCITE GROUP.

This comprises a number of minerals that frequently replace one another (as in the basalts), and which have a sufficient similarity to be noted together.

NEPHELINE, ELAEOLITE, CANCRINITE.

The first occurs in many lavas, replaces labradorite in the basalt group, and is essential in phonolite. It occurs in glassy crystals under the above name, and in coarse crystals, or masses, with a greasy luster, under the name of *elaeolite*. The color of the former is white or yellowish; of the latter greenish, brownish, and sometimes reddish. These minerals are allied to the feldspars and contain from 13–21 per cent. of soda, and 1–7 per cent. of potash. They crystallize in the hexagonal system. An alteration product of similar formula to nepheline is *cancrinite*. It contains 3–6 per cent. of carbonic acid. These alter quite readily and become, by alteration, *thomsonite* and *natrolite*.

Elaeolite has been also noted as altering to mica and opal.

SODALITE, HAÜYNE, AND NOSITE.

These are all silicates of alumina and soda, with a third combination that is different in each species. All crystallize in the isometric system, the usual form being the rhombic dodecahedron, all cleave parallel to its faces. BB. sodalite fuses with intumescence to a colorless glass; when fused with microcosmic salt and oxide of copper it gives the blue coloration to the flame, characteristic of the presence of chlorine.

Haüyne and nosite when fused with carbonate of soda yield the usual reaction for sulphuric acid. All three of these minerals are decomposed by acids with separation of gelatinous silica. In the case of haüyne sulphuretted hydrogen is evolved when the mineral is treated with sulphuric acid, but nosite under similar circumstances evolves none. Haüyne usually has a stronger blue color than nosite; but a blue coloration may be imparted to nosite by heating the mineral; the phenomenon being due to the change which the contained sulphide of sodium undergoes, and in the rocks of the Laacher See in the Eifel, which contain nosite, haüyne is found as a substitute in those ejected blocks and lapilli which bear traces of fusion. These facts indicate the probability that haüyne and nosite are mere varieties of the same mineral species. The red color of some haüyne is due to the presence of scales of peroxide of iron. Sodalite occurs both crystalline and colloid. It is usually yellowish, gray or blue. It alters to kaolin, like the feldspars.

LEUCITE.

Tetragonal. It is confined to volcanic rocks in Europe, the United States, and an island near Java. It has a conchoidal fracture. Color grayish, reddish-white, ashen-gray. It alters to feldspar, nepheline, and kaolin.

	H.	*G.*	*Luster.*	*Color.*	*Texture and Structure.*
25. Nepheline.	5.5—6	2.5—2.65	Vitreous.	White or yellowish.	Crystalline; thin columnar; compact; massive.
a. Elaeolite.		2.6	Greasy.	Dark-green; bluish-gray; brownish; brick-red.	Coarse crystalline; massive.
b. Cancrinite.		2.42—2.5	Sub-vitreous; slightly pearly and greasy.	White; gray; yellow; green; blue; reddish.	Crystalline; thin columnar, and massive.
26. Sodalite.		2.1–2.4	Vitreous, inclining to greasy.		Crystalline; massive.
27. Haüyne.		2.4–2.5		Bright-blue; sky-blue; greenish-blue; asparagus-green.	Commonly in rounded grains often looking like crystals with a fused surface.
28. Nosite.	5.5	2.2–2.4		Grayish; bluish; brownish; black.	Crystalline; granular; massive.
29. Leucite.	5.5—6	2.44—2.56	Vitreous.	White; ash-gray; smoke-gray.	Disseminated in grains; rarely, massive granular.

B.B.	*Chem.*	*Remarks.*
Fuses with difficulty to a vescicular glass; with cobalt solution the fused edges are colored blue.	Gelatinizes with acids.	Essential in nepheline-dolerite and phonolite; occurs in metamorphic rocks allied to granite and gneiss.
Fuses readily at 3.5 to a vescicular glass.		Essential in zircon-syenite, foyaite, and miascite.
In the closed tube, gives water; fuses 2.5, with intumescence to a white blebby glass.	Effervesces with HCl; forms a jelly on heating, and not before.	An altered nepheline or elaeolite. Essential in ditroite.
In the closed tube the blue varieties become white and opaque; fuses with intumescence at 3.5—4 to a colorless glass; gives reaction for Cl.	Decomposed by HCl and HNO_3 with separation of gelatinous silica.	Occurs in granite, syenite, basalt and volcanic rocks; essential in miascite.
In the closed tube retains its color; in the forceps fuses 4.5 to a white glass; with soda on charcoal gives the reaction for sulphur.	Decomposed by HCl with separation of gelatinous silica.	Occurs in basaltic lavas and phonolite; essential in haüynophyr.
	Gelatinizes with acids; gives no H_2S.	Occurs in phonolite and modern basaltic lavas.
Infusible; with cobalt solution gives a blue color.	Decomposed by HCl without gelatinizing.	Essential in leucitophyr; is confined to volcanic rocks.

OLIVINE—IOLITE GROUP.

OLIVINE.

This is the common variety of chrysolite and is a constituent of many eruptive rocks, in which it occurs sometimes in the form of crystals whose angles frequently appear more or less rounded, and sometimes as rounded granules. Olivine varies in hardness from 6.5 to 7. Its fracture is conchoidal and its color is not only olive or bottle-green, but at times brownish or yellowish. Where, therefore, olivine occurs in rounded imbedded granules, and displays neither its characteristic form of crystal nor its common green color, its hardness and its conchoidal fracture cause it greatly to resemble quartz, which also occurs in rounded granules in certain rocks of eruptive origin, but a mistake of this kind is only likely to occur in the hasty examination of hand-specimens in the field. Powdered olivine is easily decomposed by hot hydrochloric acid or by sulphuric acid; separation of gelatinous silica occurring in either case. Before the blowpipe alone, only the highly ferruginous varieties are fusible, forming a black magnetic globule; but with borax the ordinary olivine may be fused to a clear green bead. The alterations which olivine undergoes are either due to peroxidation of the iron, or to its removal by water charged with carbonic acid, in which case some of the magnesia may also be removed. Changes of the former class cause the mineral to assume a reddish or brownish color, and sometimes render it iridescent. This process, when further advanced, sets up a micaceous structure in the mineral, and Dana mentions an instance in which a basalt, owing to this change in the olivine, was represented to be a mica slate. Changes of the latter class, viz., by water charged with cabonic acid, give rise to the formation of serpentine, steatite, etc.

GARNET.*

Isometric, the common form being the rhombic dodecahedron. The garnets vary in hardness from 6.5 to 7.5. They have a subconchoidal or uneven fracture, and they all afford an approximately white streak. Before the blowpipe most of them fuse easily, but, in accordance with the different chemical composition of the various species, they give different blowpipe-reactions with the fluxes, in which the iron reactions dominate. In chemical composition the garnets are essentially unisilicates of different sesquioxides and protoxides. The sesquioxides are those of aluminium, iron and chromium; sometimes also of manganese, while the protoxides are those of iron, calcium, magnesium or manganese. The percentage of silica in the various sub-species is tolerably uniform, ranging from 35 to 40 per cent. Although garnets occur in some eruptive rocks, yet they are most plentiful in those which have undergone strong metamorphism, and they are especially common in granulite, gneiss, mica schist, talcose and chloritic slates, and other schistose metamorphic rocks. They also occur in serpentines, and granular and crystalline limestones. They are essential in garnet rock, eklogite, eulisite and kinzigite.

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*The common black garnet is sometimes called *melanite* and occurs in nosite-melanite tephrite, a variety of leucite basalt.

ZIRCON.

Tetragonal. It is met with in some lavas and volcanic ejected blocks, also in zircon-syenite, granular limestone, and the crystalline schists. In chemical composition it is essentially silicate of zirconia and, since it contains no protoxides, it is one of the least liable to undergo alteration. It, however, at times becomes hydrous, loses silica, and becomes partly replaced by other substances.

VESUVIANITE (*Idocrase*).

This is partly of igneous origin, as it is found in artificial slags, and partly the result of alteration. It occurs in the old vesuvian lavas, in serpentine, dolomite, and some of the metamorphic schists. It is essential to egeran.

In its chemical composition it is allied to the lime-alumina garnet. In the vesuvian lavas it is associated with garnet, mica and nepheline.

EPIDOTE: ZOISITE, SAUSSURITE.

Epidote is monoclinic. Cleavage parallel to the orthopinakoid perfect; parallel to the basal plane, very perfect. The cleavage planes intersect at an angle of 115° 24′. Color usually green or yellowish-green, sometimes brown. Epidote occurs at times in a granular or massive condition; the crystals commonly form radiate or fan-shaped groups, and either form nests, or line fissures and cavities. The mineral is essentially an alteration-product, consisting of silicate of alumina, lime, and peroxide of iron, with variable amounts of oxide of manganese and water. Before the blowpipe it usually gives an iron or manganese reaction with fluxes. There are several varieties, one containing about 14 per cent of manganese oxides. The way in which epidote occurs in rocks, forming little fan-shaped aggregates of radiating needles or fibers along fissures, etc., its bright yellowish-green color, and its strong pleochroism — all of these characters taken in conjunction serve, as a rule, to distinguish it from other minerals. Chlorite is one of the minerals which most it resembles. It occurs in syenite, granite, gneiss and other schists, and is essential in epidosite.

Zoisite and saussurite are orthorhombic, and thus differ from epidote.

The former is generally crystalline: colors white to gray and brown; occurs in granular limestone and granite. The latter is generally compact and fine-grained; colors pale bluish-green, greenish-gray to white; is very tough; essential in euphotide.

[NOTE.—The name *saussurite* has been applied to forms of garnet, meionite, and labradorite. It forms, with smaragdite, the euphotide of the Alps. The majority of authorities have narrowed the use of the name to compact zoisite, above, and a compact form of labradorite, which bears to that mineral the relation of felsite to the acid feldspars. The saussurite of euphotide is ascribed to both these varieties. Continental authorities place it under labradorite, while Dana, from its composition, and its high specific gravity (3.6–3.8), claims it as zoisite.]

IOLITE (*Dichroite*, *Cordierite*).

This occurs principally in the metamorphic, rarely in the volcanic rocks. It sometimes replaces quartz, as in cordierite granite, dichroite rock. It occurs in crystals, and also as massive and compact.

	H.	*Gr.*	*Texture, etc.*	*Luster.*	*Color.*
30. Olivine.	6.5—7	3.33	Crystalline; massive; compact; usually in imbedded grains.	Vitreous.	Dark yellowish-green to bottle-green.
31. Garnet.	6.5—7.5	3.15—4.3	Crystalline; granular; massive; sometimes friable; sometimes compact like 35. *a*.	Vitreous to resinous.	White, red, brown, yellow, black.
32. Zircon.	7.5	4—4.75	Crystalline; granular.	Adamantine.	Colorless; yellow; gray; reddish-brown.
33. Vesuvianite.	6.5	3.4	Crystalline; granular; massive.	Vitreous to resinous.	Brown to green; sometimes sulphur-yellow and pale-blue.
34. Epidote.	6—7	3.25—3.5	Crystalline; fibrous; granular; massive.	Vitreous; on cleavages inclining to pearly.	Various shades of green to black; also yellow, red, gray and grayish-white.
35. Zoisite.	6—6.5	3.11—3.38	In crystalline masses.	Pearly; vitreous on a fracture.	Gray to white and brown.
a. Saussurite.	6.5—7	3.6—3.8	Compact and fine grained.	In a less degree.	Bluish-green; greenish-gray to white.
36. Iolite.	7—7.5	2.6	Crytalline; massive; compact.	Vitreous.	Blue; blue along the vertical axis, yellowish-gray perpendicular to it.

B-B.	*Chem.*	*Weathering.*	*Remarks.*
Whitens, but is infusible; varieties with iron fuse to a black magnetic globule.	Decomposed by HCl and H_2SO_4 with separation of gelatinous silica.	Alters to serpentine, limonite, etc.	A common constituent of eruptive rocks; occurs in lherzolite, gabbro and basalt; essential in dunite.
Most varieties fuse 3—3.5 easily to a light-brown or black glass.	Some varieties are decomposed by acids; nearly all are, after ignition, by HCl, and generally with separation of gelatinous silica.	To steatite, chlorite, serpentine, etc.	Essential in garnet rock, eklogite, eulisite and kinzigite; occurs in the metamorphic schists; in granite, syenites and, occasionally, in lavas.
Infusible.	In bulk, unacted on by acids; when in fine powder is decomposed by concentrated H_2SO_4.	One of the least alterable of minerals.	Essential in zircon-syenite; occurs in granular limestone, the crystalline schists, granite, etc.
Fuses at 3 with intumescence to a greenish or brownish glass.	Partly decomposed by HCl; completely after ignition.	As in 31.	Essential in egeran; occurs in old Vesuvian lavas.
In the closed tube gives water; fuses at 3—3.5 with intumescence to a dark-brown or black magnetic mass.	Partly decomposed by HCl, but, when previously ignited, it gelatinizes.	Very slightly.	Essential in epidosite; occurs in crystalline rocks.
Swells up and fuses 3—3.5 to a white blebby mass.	Not decomposed by acids; gelatinizes with HCl when previously heated.		Found in metamorphic rocks.
			Essential in euphotide.
Loses its transparency and fuses 5—5.5.	Only partly decomposed by acids.	Very readily; it is usually surrounded by a crust of altered mineral.	Occurs in metamorphic crystalline rocks; rarely in volcanic rocks.

TOURMALINE—STAUROLITE GROUP.

TOURMALINE (*Schorl*).

Rhombohedral. The crystals commonly occur in long prismatic forms. The development is usually hemihedral, thus giving rise to triangular prisms. The crystals, when heated and freely suspended, exhibit polar electricity, a phenomenon which usually accompanies hemimorphism. Cleavage rhombohedral but very imperfect. Crystals generally striated longitudinally. They often form radiate groups. The chemical composition of tourmaline is variable. All the varieties contain silicate of alumina with about 4 to 10 per cent. of boracic acid, some contain protoxide, some peroxide, and some both protoxide and peroxide of iron. Magnesia, soda, lime, phosphoric acid, lithia and fluorine also occur in some varieties. The fusibility of some varieties is effected with more or less difficulty before the blowpipe. Others fuse with comparative ease; in some cases the fusion is accompanied by intumescence. Heated with powdered fluor-spar and bi-sulphate of potash, all the varieties impart to the oxidizing flame the green coloration indicative of boracic acid. The black variety of tourmaline is termed schorl, and is of frequent occurrence in certain rocks, especially in granites and the metamorphic schists. It is essential in schorl rock and accessory to topaz rock and others.

ANDALUSITE (*Chiastolite.*)

Orthorhombic. The crystals, especially the larger ones, are usually incrusted with and penetrated by scales of mica. At times they are feebly translucent and very rarely transparent. The cleavage is very indistinct. Andalusite sometimes occurs in a granular condition. It is most commonly met with in mica schist and slaty rocks.

The variety chiastolite or macle, so named from the spots and cruciform markings which occur in the interior of the crystals, is met with only in metamorphic slates.

CYANITE.

Triclinic. Chemical composition similar to that of andalusite. The crystals are generally long-bladed prisms. The cleavages are prismatic and basal, the former being tolerably distinct parallel to the broad faces, but less so in the direction of the narrow ones. The basal cleavage enables the prisms to be easily broken in a transverse direction. The crystals are seldom terminated. It also occurs in radiating or interlacing fibrous conditions. It is transparent, with a vitreous luster, and is colored blue, or grayish-blue and white, individual prisms often showing a succession of blue and colorless bands which graduate into one another. Occurs in the metamorphic crystalline schists.

TOPAZ.

Orthorhombic. Occurs in hemihedral crystals with a highly perfect basal cleavage; also firm columnar; also granular. It is infusible under the blowpipe and insoluble in acids. It is not a mineral of common occurrence in rocks. It only attains importance as a rock-component in the

'Topazfels' of Schneckenstein in Saxony; still it is occasionally met with as an accessory constituent of certain rocks.

STAUROLITE.

Orthorhombic. Usually crystalline, with crystals imbedded. Twins cruciform. Common in mica schist, argillaceous mica schist, and gneiss. Does not occur by itself and is only an accessory in the rocks where it occurs.

ZEOLITE GROUP.

These occur in the amygdaloidal cavities of igneous rocks, and are the result of exfiltration and crystallization after the formation of the rock in which they exist. The lime-zeolites, thompson ite, scolecite, etc., are indicative of a lime feldspar in the original rock. In general, except analcite, which comprises two-thirds of a nepheline-dolerite from the Cyclades, and gives it the name *analcymite*, they do not cause any varieties in rocks.

Analcite is isometric and occurs usually in trapezohedrons. It is also granular massive. H. 5—5–5. Gr. 2.22—2.29. Luster, vitreous. Colorless; white. Transparent to nearly opaque. BB. at first becomes opaque and fuses quietly at 2.5 to a colorless glass. Gelatinizes with muriatic acid. The other minerals mentioned in the list on page 10, need not be reviewed here, as they occur under such circumstances as to be readily distinguished by one having a knowledge of mineralogy.

	H.	*Gr.*	*Texture, etc.*	*Luster.*	*Color.*	*B.B.*	*Chem.*	*Weathers.*	*Remarks,*
37. Tourmaline.	7—7.5	2.94—3.3	Crystalline; massive; compact; columnar.	Vitreous	Black; brownish-black; bluish-black.	The common varieties fuse more or less easily to a variously colored glass or slag.	Not decomposed by acids; after ignition perfectly decomposed by H_2SO_4.	Alters to steatite, lepidolite, etc.	Occurs in metamorphic rocks.
38. Andalusite.	7.5; in some opaque kinds, 3—6.	3.1—3.2	Crystalline; massive; sub-columnar; granular.	Vitreous; often weak.	Whitish; red; brown; green.	Infusible; with cobalt solution gives a blue color.	Not decomposed by acids.	To kaolin, to mica, cyanite, etc.	In argillaceous and other imperfectly crystalline schists.
39. Cyanite.	5—7.25	3.45—3.7	Long-bladed crystals.	Vitreous to pearly.	Blue; white, gray; green; black.	Same as 38.		To talc and steatite.	In gneiss and mica schist.
40. Topaz.	8.	3.4—3.65	Crystalline; columnar; granular.	Vitreous	Yellow; white; greenish; bluish; reddish.	Same as 38.	Partially attacked by H_2SO_4.	To steatite and kaolin.	In gneiss and granite; essential in topaz rock.
41. Staurolite.	7—7.5	3.4—3.8	Crystalline.	Sub-vitreous to resinous.	Brown to brownish-black.	Most varieties infusible.	Imperfectly decomposed by H_2SO_4.	To steatite.	In mica schist, argillaceous schist, and gneiss.

PART II.

THE ROCKS.

CHAPTER I.

Rocks may be divided into:

PRIMARY, which show no traces, to the naked eye, of deriviation from older formations;

SECONDARY, which have been thus derived from the disintegration of other rocks, and, by heat, moisture, and pressure, or by any one of these agents, have been more or less consolidated. Secondary rocks may be subdivided according to the manner in which the consolidation took place, into:

SEDIMENTARY.—The products of deposit;

METAMORPHIC.—The product of the change in sedimentary rocks through the action of the agents noted above, but in their mineralogical composition allied to the primary rocks, from which some can with difficulty be distinguished;

SPECIAL, whose origin is doubtful to the naked eye, and also those composed of one mineral.

The *primary* rocks are the products of igneous fusion, or metamorphism so complete as to have destroyed all traces of sedimentary action. By igneous fusion is meant the state existing in volcanoes at the present date. In either case, the material has solidified from a plastic state and, according to the rapidity with which it has cooled, it has formed a compact, or a crystalline rock. At an earlier stage of the science, primary or igneous rocks were divided into *volcanic* and *plu-*

tonic states. The former comprised all rocks that had cooled at or near the surface, and which were characterized by the presence of tuff, scoria, etc.; the latter included those that had never come to the surface, but had solidified slowly at great depths, and therefore under great pressure, and which were characterized by a more or less coarse crystalline-granular texture. Laboratory experiments have shown that the presence of water will greatly reduce the temperature necessary for fusion, so that a complete metamorphosis will produce a state of plasticity. In case fractures are formed in the rocks enclosing the region of metamorphosis, the plastic mass will be forced into them as easily as if the fusion has been due to heat alone, and this will account for many of the eruptive granites, gneisses, etc. The Comstock Lode and other masses of primary rocks that can be studied at great depths, have shown that this division cannot be maintained, because the same mass will show varying states at different depths, and rocks of different names are shown to have belonged to the same igneous mass. The subject is not yet sufficiently settled to allow the dividing lines to be drawn, and in the following pages a provisional scheme for separating the various species will be given, that may be changed or entirely discarded if the future state of the science warrants such an action.

For the purpose of definition, in this part of the book, the groups will be separated according to mineralogical composition, and, after defining the prominent types, rocks of similar composition, texture, and structure will be grouped under them.

CHAPTER II.

PRIMARY ROCKS.

The two principal combinations under this head are:

ACID ROCKS, distinguished by their large proportion of quartz; by a feldspar rich in silica, combined with mica and frequently, amphibole; by their having generally a light color; and by their being frequently vitreous, but seldom vescicular or amygdaloidal.

BASIC ROCKS, poor in silica (in its stead frequently nepheline or leucite) combined with pyroxene, amphibole, magnesia, mica, magnetite, etc.; by their being frequently vescicular and amygdaloidal, but seldom vitreous; and by their general dark color.

Acid rocks are more general; basic rocks, more local, in their distribution.

This classification may be crossed by another, depending upon the texture and structure, as before noted, and we may have the general divisions into *vitreous* and *crystalline*.

ACID VITREOUS ROCKS.

These are compounds of feldspar (orthoclase or sanidine, sometimes oligoclase) with mica or even quartz. The principal mass is vitreous or enamel-like, and may be homogeneous, porphyritic, or vescicular. They are all untouched by acids.

Sp. Gr. . . .	2.2—2.5
Contains silica, . . .	63—82 p. c.

The rocks of this class fall under two divisions, according to the conditions under which they are found, *perlite*, *obsidian*, and *pumice* are the results of the cooling of the mass at the surface, while *pitchstone* and *pitchstone-porphyry* are similar results where there has been rapid cooling under pressure; the former are volcanic and are associated with the trachytes; the latter with the granites.

PERLITE.—*Pearlstone.*

A matrix sometimes glassy, more frequently enamel-like, pearly, or greasy on a fresh fracture, containing round grains of a concentric or shaly nature.

Sp. Gr. . . .	2.3—2.4; 2.25
Contains silica, . .	70—77 p. c.

The color is mostly pale-gray or bluish-gray, sometimes yellowish-brown. The structure is probably similar to the spheroidal structure of some basalts, and may be due to the formation of concentric zones on cooling. Perlites occur massive, porphyritic, vescicular; sometimes lose their luster, through weathering, and become kaolinized and dull.

OBSIDIAN.

Obsidian is a volcanic glass, sometimes porphyritic from sanidine crystals. It is the result of the quick solidification of lavas which, if slowly cooled, would become crystalline, and would be called trachyte, rhyolite, etc. When obsidian becomes vescicular it is called pumice.

Sp. Gr.	2.3—2.5
Contains silica, . . .	72—82 p. c.
Hardness, ...	6—7

These two rocks are states of the same mass, depending upon their position. The outer surface of the obsidian flow is generally pumiceous. Obsidian is a true natural glass without a trace of a crystalline structure. It is homogeneous in appearance; has a strong vitreous luster, and a conchoidal fracture. The color is black, brown, or greenish in obsidian; white or yellowish-gray in pumice. BB. *obsidian is fusible on the edges of thin splinters, pumice fuses more readily.* They occur in districts where trachyte rocks are common.

PITCHSTONE and PITCHSTONE-PORPHYRY.

The principal mass is homogeneous; of vitreous pitch-like appearance; conchoidal fracture; resinous luster, translucent at the edges; color yellow, red, brown, black, and green; it sometimes encloses (porphyritically) small crystals of vitreous feldspar, grains of quartz, and laminae of mica; frequently also balls of felsite.

Sp. Gr.	2.2—2.3
Contains silica, . .	63—75 p. c.
Hardness, . . .	5—6

In chemical composition the pitchstones resemble obsidian, but contain from 4–10 p. c. of water. BB. *all varieties melt, with more or less difficulty, to a frothy glass, or to a greenish or grayish enamel, and give water in the closed tube: untouched by acids.*

The pitchstones bear the same relation to the felstones that the perlites and obsidians do to the trachytes. Vogelsang has given the name *vitrophyre* to pitchstone-porphyry.

BASIC VITREOUS ROCKS.

These are compounds of labradorite (or nepheline), pyroxene, olivine, and magnetite. They are decomposed with gelatinization in hydrochloric acid.

TACHYLITE. *Vitreous Basalt.*

This is a black or brown glass resembling obsidian in appearance, but differing in the fact that it seldom occurs in large masses; has a splintery fracture; and is decomposed by acid.

Sp. Gr.	2.5
Contains silica,	50—55 p. c.
Hardness.	6.5

The tachylites occur as thin crusts at the sides or margins of basalt dykes. The great exception to this rule occurs in the Kilauea lavas, which are of great extent; are rich in olivine; and are highly vescicular. To a certain extent, some tachylites have a sub-conchoidal fracture. The vescicular kinds are also called pumice. It contains 6–7 per cent. of water: *fuses easily to a dark slaggy glass; gelatinizes with HCl.*

ACID CRYSTALLINE ROCKS.

These are compounds of a feldspar (orthoclase or sanidine, sometimes oligoclase or albite), quartz, mica and hornblende.

Sp. Gr.	2.3—2.8; 2.6
Contains silica,	50—67 p. c.
Hardness,	5—6.5

This class may be divided into two sub-classes according to the size of the particles in the mass, and these will be called *crystalline-granular* and *crypto-crystalline.*

ACID CRYSTALLINE-GRANULAR SUB-CLASS.

These have the principal mass generally crystalline-granular or coarse crystalline; exceptionally, fine or crypto-crystalline.

Sp. Gr.	2.6—2.8
Contains silica, . .	62—81 p. c.
Hardness, . . .	6—6.2

In this class the several mineral grains are finely knit together by their crystalline surfaces, without any uniting medium; are of a size to be readily recognized. The feldspar is the predominant ingredient and is generally orthoclase (sometimes oligoclase accompanies it). The GRANITES are the type of this sub-class.

GRANITE.

A crystalline-granular compound of orthoclase, quartz, and mica. In certain varieties there occur chlorite, talc, hornblende, tourmaline and pyrites. Sp. Gr., etc., as above.

The granites (from the Latin *granum*, a grain) are essentially, as their name implies, crystalline-granular rocks. There is, however, considerable variation in the mineral constitution of granites. In some the felspathic component is not merely orthoclase; plagioclastic felspars, such as albite and oligoclase being frequently present, while the mica, which is usually muscovite or biotite, may at times be represented by lepidolite, lepidomelane, or other micas. Other minerals, which are not regarded as essential constituents of granite, are often present. When widely disseminated, these accessory constituents play only a very subordinate part; but, in certain limited areas, they are often developed in sufficient quantity to impart a distinctive character to the rock. Thus, for example, tourmaline frequently occurs in considerable quantity in granitic masses at or near their contact with other rocks, sometimes to such an extent that the term tourmaline granite is applied to the rock. Apatite and magnetite are also minerals of common occurrence in granites. Epidote and garnets are less common, but are often met with. Talc, beryl, iolite, andalusite, topaz, cassiterite, and hematite are occasionally met with in granite rocks. Hornblende is of common occurrence, and, when tolerably plentiful, the rock is then termed hornblendic or syenitic granite.

Granite rocks vary very considerably in texture and in structural characters. They are frequently porphyritic. Crystals of orthoclase several inches in length being of common occurrence in some, while, in others, the mica (usually muscovite) forms, by its conspicuous development, the dominant mineral. In their order of solidification, or crystallization, quartz appears to come last, and although it sometimes occurs in hexagonal pyramids or in combinations of the pyramid and prism, still its development, as a rule, seems to have been imperfect, and to have resulted mainly in irregularly shaped, angular, crystalline grains. The orthoclase in granites varies in color. In some it is red, often of a flesh-red or pink tint, in others white, gray, or yellowish. It very commonly occurs in Carlsbad twins. When granites are weathered, the felspar crystals are converted into kaolin and the rock in course of time crumbles away. The crystals of orthoclase are not always well developed in granites; they sometimes have very irregular contours, and occasionally their angles are rounded. One of the arguments against the igneous origin of granite is that in granite the quartz has a specific gravity of 2.6, identical with that of silica derived from aqueous solution, while the specific gravity of fused silica is only 2.2.

In *porphyritic granite* the feldspar crystals (orthoclase) are large and well developed. *The principal mass is granular.*

GRAPHIC GRANITE, PEGMATITE.

A coarsely and irregularly constituted compound of orthoclase, quartz, and usually silvery-white mica. The first is predominant in large crystals and is penetrated by the quartz, so that on certain cleavage planes it produces figures like writing.

Contains silica, . . . 78 p. c.

The fine varieties are called *graphic granite*, the coarser, *pegmatite*. Both form subordinate masses in ordinary granite. The feldspar is white, yellow, green, red, etc.

PROTOGINE.

A granite in which talc, chlorite, or decomposed mica replaces the ordinary mica.

SYENITIC GRANITE.

A granite with hornblende.

Sp. Gr.	2.6—2.9
Contains silica, . .	60—75 p. c.

This is a transition between granite and syenite, and by the suppression of the quartz and mica, the former will pass into the latter.

TOURMALINE GRANITE, LUXULLIANITE.

A granite where tourmaline replaces mica.

Sp. Gr. . . . . 2.6—2.9

The first is usually fine-grained and forms veins in other granite; *luxullianite* is coarse crystalline. In the latter the orthoclase is flesh-red; the tourmaline black or greenish-black and distributed in irregular nests or patches.

GRANITITE.

A granite containing flesh-red orthoclase, much oliogoclase, quartz, blackish-green magnesian mica and no white mica.

The orthoclase and quartz are the principal constituents.

CORDIERITE GRANITE.

A granite in which the mica is more or less replaced by iolite.

Sp. Gr. . . . . 2.6—2.7

It is local in its occurrence and has been found in Norway, Greenland, and Bavaria.

APLITE.

A crystalline-granular compound of orthoclase and quartz.

It may be considered as a granite without mica. Graphic granite may be taken as a variety of this rock. When it becomes schistose it passes into granulite, and may be distinguished from the latter by the absence of garnet and cyanite which are generally characteristic of granulite. From its wanting mica it is called by the Germans (Halbgranit) semi-granite.

GREISEN.

A crystalline-granular compound of quartz and lepidolite.

This is a granite without feldspar, and, were it foliated, it would become mica-schist. It is a rock of common occurrence in Saxony and Cornwall, and accompanies tin ore. The predominant mineral is quartz.

ACID CRYPTO-CRYSTALLINE SUB-CLASS.

These have the principal mass generally fine or crypto-crystalline; are frequently porphyritic.

Sp. Gr.	2.5—2.8
Contains silica, . .	50—81 p. c.
Hardness, . . .	5—6

In this class the several mineral grains are cemented together by a paste or ground-mass, which frequently occurs alone, in the more compact forms. This principal mass may be rough, as in the trachytes; smooth and stony, as in the felstones; or enamel-like, as in the liparites, though it never becomes entirely glassy, as in the first class previously defined.

TRACHYTE GROUP.

These have a rough principal mass consisting of sanidine, oligoclase (or even albite or labradorite), with some hornblende or augite and dark colored mica. In this matrix, some of the above minerals are frequently, distinctly and separately developed and imbedded.

Sp. Gr.	2.4—2.8
Contains silica, . .	62—67 p. c.
Hardness, . . .	5—6

The rocks which have been included under this name are exceedingly numerous, and the term in its present acceptation has still a very wide range. The usual constituents of trachyte are sanidine, oligoclase, hornblende, sometimes augite, magnesian mica, magnetite, titaniferous-iron, tridymite,* and at times some other minerals, such as sodalite, haüyne, nosite, sphene, leucite, and olivine, which may, for the most part, be regarded as accessories. Plagioclastic feldspar is generally associated to a greater or less extent with the sanidine in these rocks; hence some good authorities consider their division into sanidine trachytes and sanidine-oligoclase trachytes is of little account. The sodalite-, haüyne-, and nosean-bearing trachytes are, to some extent, analogous to the phonolites. The name trachyte is from the Greek word meaning *rough*, in allusion to the rough, scraping sensation which the fresh surfaces of these rocks give when rubbed by the fingers. They are composed of grains, often fine, enclosed with the feldspar crystals, leaving spaces between them, which gives them a porous texture, an irregular fracture, an uneven aspect, and the rough feel mentioned above. The luster is dull, often clayey in some kinds, and is semi-vitreous. The feldspar is the predominant mineral and is usually sanidine. The prevailing colors are yellowish-white, reddish, gray; rarely bluish.

SANIDINE TRACHYTE.

A principal mass of an aphanitic or micro-crystalline character consisting of sanidine crystals, with some hornblende or mica as subordinate ingredients.

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* Tridymite, a peculiar form of crystalline silica. (See Dana's Mineralogy.)

Sp. Gr.	2.4—2.6
Contains silica, . .	59—60 p. c.

In this compound of the above minerals, occur, as accessories, magnetite, sodalite, haüyne, olivine, titanite, and augite or quartz. Generally no quartz is visible to the naked eye. The sanidine frequently occurs porphyritically. The color varies from a grayish-white to a dark brownish-gray. In most cases the texture is porphyritic, with granular or compact matrix; some varieties are vescicular and even scoriaceous at the surfaces, but never amygdaloidal. It weathers to a claystone. The sanidine-trachyte of the Laacher See contains haüyne to such an extent as to be called *haüyne-trachyte.*

SANIDINE–OLIGOCLASE TRACHYTE.

A crystalline compound of sanidine and oligoclase, with biotite and hornblende, also some pyroxene, magnetite and titanite.

Sp. Gr.	2.6—2.7
Contains silica, . .	60–67 p. c.

This is the Drachenfels trachyte, near Bonn, with large crystals of sanidine porphyritically enclosed. About 5 per cent. of the matrix is soda. The above division into sanidine- and sanidine-oligoclase-trachyte is given here because it is still accepted by some authorities, though there is generally some oligoclase in the sanidine trachytes.

DOMITE (OLIGOCLASE–TRACHYTE.)

A compound of oligoclase, hornblende or augite, and dark-colored mica. The matrix is micro-granular.

Sp. Gr.	2.6—2.8
Contains silica, . .	62—68 p. c.

This rock is a transition between trachyte and trachydolerite or andesite and passes into them by an increase in the amount of hornblende or pyroxene. It however contains tridymite and is thus classed among the acid rocks. The variety from the Siebengebirge is found in a fresh state; that from the Puy de Dôme (hence the name) is decomposed and crumbly.

RHYOLITE, LIPARITE, QUARTZ-TRACHYTE GROUP.

These have a compact, shining, semi-vitreous matrix, enclosing grains or crystals of sanidine, oligoclase, mica, and even quartz.

Sp. Gr.	2.4—2.6
Contains silica, . .	67—82 p. c.

The matrix of quartz-trachytes appears, to the naked eye, as a compact, or very finely-granular, substance, often rough and porous; it sometimes resembles hornstone, while, at others, it has a dull, earthly or kaolinized appearance. It varies considerably in color, brick-red, reddish-gray and yellowish- and brownish-white being some of the most common. The principal bodies porphyritically developed in this matrix are crystals and crystalline granules of sanidine and quartz, while plagioclastic feldspars, hornblende, and magnesian mica (biotite) are often also well developed. The sanidine crystals in the quartz-trachytes very frequently show twinning on the Carlsbad type. These crystals often appear much fissured and fractured. Plagioclastic feldspars, although frequently present, occur, as a rule, only very sparsely in the quartz-rhyolites, and are often so altered that the characteristic twin lamellæ are scarcely, if at all, perceptible, since they are sometimes completely converted into kaolin. The quartz occurs both in roundish grains and in definite crystals. A little biotite frequently occurs in the quartz-trachytes. Hornblende is seldom plentiful. Magnetite is generally present, but only in small quantity. Hard, vescicular varieties of quartz-trachyte occur in some localities, and are known by the name millstone-porphyry. The vescicles are often lined with chalcedony or quartz. Nodules or balls of chalcedony and opal are met with in the Hungarian rocks. Some of the quartz-trachytes show a fissile, slaty, or slabby structure, which sometimes originates in the varying character of different bands which exist in the rock, or else in a parallel arrangement of the sanidine crystals.

LIPARITE. TRACHYTE–PORPHYRY.

A compact felsitic mass, containing crystals of feldspar, sometimes quartz and mica. The matrix is felsitic and is rather more vitreous than that of the quartz-porphyries, especially on a fresh fracture.

Sp. Gr.	2.4—2.6
Contains silica, . .	67—81 p. c.

In some cases trachyte-porphyries resemble, in single specimens, quartz-porphyries, so that only their connection with trachytes will decide as to which they belong. They are usually light-colored. In some varieties the matrix becomes enamel-like and the rock passes into *perlite*. This variety is called *perlite porphyry*. When it contains vescicular cavities, whose sides are lined with chalcedony or quartz, it becomes *millstone-porphyry.* These cavities are never entirely filled so as to become amygdaloidal. In some cases a slaty structure, produced by alternating flows of varying composition, is called *slaty trachyte-porphyry.*

FELSITE—PORPHYRY GROUP.

These have a compact, dull or smooth matrix, either occurring alone, or enclosing crystals or crystalline grains of feldspar, quartz and mica.

Sp. Gr.	2.5—2.7
Contains silica, . .	61—81 p. c.
Hardness, . . .	5.5—6.5

The term *porphyry* is used here and hereafter to designate all porphyritic rocks with a quartz-felsitic matrix. It is thus narrowed in its meaning, and excludes all quartzless porphyritic rocks. These will be called, after the analogy of some authorities, *porphyrites.* *Porphyries* contain above 60 per cent. of silica; *porphyrites*, less than that amount.

The felsitic matrix of the porphyries is generally considered to contain the essentials of granite in a compact state, and this group bears the same relation to granite that the perlites and trachyteporphyries do to trachyte.

FELSITE, FELSTONE, EURITE, PETROSILEX.

A rock of compact texture, about the hardness of feldspar, with dull or smooth conchoidal fracture; color yellowish, reddish, gray, greenish, or bluish; weathering white.

Sp. Gr.	2.5—2.7
Contains silica, . .	71—81 p. c.

The name *felsite* was given this rock by Gerhard, its discoverer, because it consisted chiefly of feldspar. Daubuisson gave it the name *eurite* from its fusibility; Brongniart called it *petrosilex*, as he supposed it to be identical with hornstone. It is an intimate crystalline-granular or cryptocrystalline mixture of orthoclase and quartz, with occasionally a little mica, and may be considered as a granite that has solidified suddenly without developing a vitreous condition, as in *pitchstone*. The presence of quartz does not interfere with the fusibility of the mixture, which is frequently greater than that of feldspar. Under the above head only the massive varieties will be included, the schistose kinds (hälleflinta, felsite-schist) will be found under the metamorphic rocks.

An admixture of orthoclase and scapolite of a compact nature, with graphite, pyrrhotite, and pyrite, as accessories, is called *wernerite* (scapolite) rock. It is of limited occurrence in the Hartz and in Sweden.

GRANITE PORPHYRY.

A compact or fine-grained felsitic base, enclosing crystals or crystalline grains of feldspar, quartz, and mica or chlorite.

Sp. Gr.	2.6—2.7
Contains silica, . .	61—64 p. c.

The matrix is yellowish, brownish or dark green. The chlorite occasions transitions to protogine. The crystals of feldspar are generally numerous and of large size. They are usually twinned crystals of orthoclase and are frequently flesh-red in color. The quartz usually forms small grains or crystals of a smoke-gray color. The dark mica is in plates or scales and frequently is so blended with the matrix as to be indistinguishable to the naked eye and to give to the matrix a dark color. When the base is fine-grained, the variety is called *Granitic Granite-Porphyry;* when the mica predominates in the matrix and the crystals or grains of quartz and feldspar are small and few in number, the rock approaches *minette* and is called *Micaceous Granite-Porphyry;* when the chlorite is predominant, it gives a greenish color to the mass, and, from being mistaken for hornblende, is sometimes called *Syenitic-porphyry.*

QUARTZ–PORPHYRY, ELVANITE.

A compact felsitic matrix, enclosing crystals or crystalline particles of feldspar and quartz.

Sp. Gr.	2.5—2.6
Contains silica, . .	70—81 p. c.

Under this head are grouped a number of varieties that will be separately described. In all these is the high degree of acidity that distinguishes them from the quartzless porphyries (porphyrites). In genuine quartz-porphyry, feldspar and quartz are the only crystals that are porphyritically developed. By weathering, a transition to a dull and earthy texture occurs in the matrix (kaolinization). The feldspar is usually orthoclase and may be recognized, by its twinned growth, from oligoclase and sanidine, which frequently occur. The quartz crystals are white, gray, or almost black; are frequently transparent; are seldom larger than a pea and are frequently rounded without any trace of crystalline structure. They sometimes almost disappear and only the amount of silica in the matrix distinguishes the rock from *feldspar porphyrite.*

The quartz-porphyries are frequently very similar to the trachyte-porphyries (*q. v.* p. 57); they seldom contain any accessory ingredients, and when they do occur, they are probably only of secondary origin, due to lateral secretion or infiltration, *e. g.*, quartz, hornstone, agate, calc-spar, etc., found in nests or concretions in the rock.

A. *Common Quartz-Porphyry*:

Compact matrix and crystals of felspar and quartz.

When the matrix is like flint, of a waxy, fine grained fracture the rock is called *hornstone-porphyry*;

When the matrix is felsitic with a smooth fracture, it is *felstone-porphyry*;

When the matrix has begun to kaolinize and is dull, it is *claystone-porphyry*. In this case the rock is soft, and can be more or less easily cut or scratched with a knife.

B. *Slaty Porphyry, Striped Porphyry.*

Composed of thin layers of somewhat dissimilar texture and color.

The fractured surface is striped like a ribbon; the different layers frequently vary greatly in the closeness of their texture; and the mass splits more readily with than across the layers. The layers are often bent and twisted.

C. *Millstone-Porphpry, Porous Porphyry.*

When the rock is penetrated by numerous small irregular cavities or geodes, which are seldom vescicular, and are more usually the result of weathering.

It obtains its name from the use to which it is put.

D. *Pyromeride* (*Ball Porphyry*).

In addition to the usual crystals, the matrix contains balls of felsite.

The small balls are radial in their structure, the larger are geodic, or are formed of concentric shells. The cavities in them are filled with hornstone, agate, etc.

INTERMEDIATE CRYSTALLINE ROCKS.

There are many rocks that vary between an acid and a basic condition, according to the amounts of their essential ingredients. It has been thought well to place these in a class by themselves and to call them *intermediate* rocks.

CRYSTALLINE–GRANULAR SUB-CLASS.

These are compounds, generally coarse-grained, of a feldspar and hornblende or pyroxene and frequently with nepheline, sodalite, black mica, zircon, and titanite. Seldom, if ever, amygdaloidal; never vescicular.

Sp. Gr.	2.6—2.9
Contains silica, . .	47—67 p. c.

SYENITE GROUP.

SYENITE.

A crystalline granular compound of orthocase or microcline and hornblende or pyroxene, and usually some titanite.

Sp. Gr.	2.6—2.9
Contains silica, . .	50—78 p. c.

The feldspar is the principal ingredient and is generally red in color, giving to the mass a brownish-red tint from its mixture with the hornblende. Mica and quartz sometimes occur and cause the rock to pass into the syenite- or hornblendic-granites; elaeolite or zircon change it to miascite and zircon syenite; a change of orthoclase to oligoclase makes it a diorite. The syenites and diorites differ only in their feldspar and it may be well to compare them and note their distinguishing features. Syenite, when fine grained, may be easily confounded with diorite. Diorite is generally more fine-grained than syenite and more green in color. As oligoclase weathers more readily than orthoclase, the feldspar in diorite decomposes faster than in syenite; feldspar and hornblende weather alike, and the rock falls into a sandy grit. Diorite contains more pyrite; syenite more titanite. When these tests fail, the fusibility of the feldspar is a certain test.

MIASCITE, DITROITE.

A crystalline-granular compound of orthoclase, nepheline, sodalite (elaeolite), and black mica; coarse grained to fine grained.

Sp. Gr.	2.6—2.7
Contains silica, . .	60 p. c.

The orthoclase is the microcline of Breithaupt, and is white or gray: the nepheline is the yellowish-white elaeolite with luster greasy or slightly resinous; the sodalite is gray or blue. As accessories occur, zircon, magnetite, pyrite, apatite, quartz, hornblende, etc., so that the rock passes into zircon-syenite, granite, and syenite. The variety *miascite* is coarse-grained and fissile with the mica in large crystals and plates; *ditroite* is more fine-grained and the materials more evenly mixed, while the blue sodalite is abundant and frequently arranged in layers.

ZIRCON-SYENITE.

A crystalline-granular compound of orthoclase, nepheline (elaeolite), and usually only a little hornblende.

Sp. Gr.	2.7—2.9
Contains silica, . .	50—55 p. c.

This may be taken as a variety of miascite, from the increase in the amount of zircon, or as a syenite with an increase in the amount of nepheline and the replacing of hornblende by zircon. It is not a widely spread rock and varies in composition in the different localities where it occurs. The zircon is red, brown or yellowish in color.

FOYAITE.

A crystalline-granular compound of orthoclase, nepheline (elaeolite), and hornblende.

Sp. Gr.	2.6
Contains silica, . .	55—60 p. c.

The orthoclase is white or grayish-white, forms long tabular twinned crystals, and is decidedly predominant. The elaeolite is reddish, with greasy luster, and occurs in single hexagonal crystals. The hornblende is greenish black, and is in columnar crystals or small grains. It is coarse to fine-grained and porphyritic, and is extensively developed in Portugal.

PYROXENE SYENITE. (AUGITE SYENITE.)

A crystalline-granular compound of orthoclase or a triclinic feldspar with hornblende or pyroxene.

Sp. Gr.	2.8—2.9
Contains silica, . .	50—58 p. c.

In this rock the pyroxene is generally plentiful, and if hornblende is present it is of the uralite variety. The orthoclase is generally the predominant feldspar, though plagioclastic ones are occasionally so. Biotite, apatite, magnetite and sphene are accessories.

DIORITE GROUP.

DIORITE.

A crystalline-granular compound of oligoclase and hornblende.

Sp. Gr.	2.6—3.0
Contains silica, . .	47—58 p. c.

The texture of the rock varies from fine to coarse grained. The color also is variable, being sometimes greenish-gray, at others greenish-black, while some of the coarser grained varieties have a speckled or blotched appearance. The rocks are sometimes very compact in texture, and are then styled diorite-aphanites. The oligoclase is usually white or greenish-white, and shows the twinning striation characteristic of triclinic feldspars. Orthoclase is sometimes present in these diorites, but it plays a subordinate part as compared with the oligoclase. The hornblende is mostly greenish-black, sometimes brownish, and occurs in long blade-like crystals or in imperfectly developed crystals, and irregular shaped patches and grains. In the finer grained and aphanitic varieties of the rock the hornblende crystals are often exceedingly small. Apatite is present in nearly all diorites. Augite is occasionally, but not often, present. Chlorite, pyrites, magnetite, and titaniferous-iron are of very common occurrence in diorites, while garnet, sphene, and epidote are also met with as accessory constituents.

The distinguishing characteristics of diorite and syenite are given under syenite (p. 63). The diorites occur porphyritic, slaty, weathered and, exceptionally, amygdaloidal. A variation in the above constituents makes a number of varieties.

A. *Anorthite Diorite.*

A crystalline-granular compound of oligoclase and anorthite, blackish-green hornblende and some quartz.

Sp. Gr.	2.76
Contains silica, . .	48 p. c.

This exists in two forms:

a.—*A rock similar to diorite, with the almost entire substitution of anorthite for oligoclase.*

This is known as *corsite*, from the island of Corsica where it exists in large masses. It is distinguished from diorite by the appearance and behavior of the feldspar:

b.—*Orbicular Diorite, Napoleonite.*

A rock in which the constituent minerals form alternating concentric layers around kernels. The kernels themselves consist (almost exclusively) either of anorthite or hornblende (not of both), and they likewise exhibit a radiated texture.

The balls are from one to three inches thick in diameter, and their section shows alternating rings of light and dark color. It occurs in Corsica near Ajaccio.

B. *Labradiorite.*

A diorite where labradorite has replaced oligoclase.

Sp. Gr.	2.7—2.9
Contains silica,	47—50 p. c.

This is much darker colored than the typical diorites and is generally more coarsely crystalline.

C. *Mica Diorite.*

A crystalline-granular compound of hornblende, oligoclase, orthoclase, mica, and a little quartz; generally of a dark color and almost black.

Sp. Gr.	2.6—2.8
Contains silica,	48 p. c.

From its composition, this is a transition between granite, syenite and diorite.

D. *Quartz Diorite.*

A diorite containing quartz.

Sp. Gr.	2.6—2.8
Contains silica,	55—60 p. c.

The quartz occurs in rounded or angular grains visible to the naked eye, seldom in regularly defined crystals. A great many diorites are quartziferous.

E. *Tonalite, Mica-Quartz-Diorite.*

A fine crystalline-granular compound of oligoclase, quartz, blackish green hornblende, and brown mica.

Sp. Gr.	2.7—2.9
Contains silica, . .	67 p. c.

The oligoclase is snow-white and contains but 57 p. c. of silica; the quartz forms one-third of the mass and is in grayish grains; there are small amounts of the hornblende and mica. It contains, as essentials, orthoclase, sphene, titanite, magnetite, pyrite, and corundum. It forms the principal mass of the Adamello Mts. in Southern Tyrol and is named from the Tonale Pass. It was once classed as a granite.

NOTE.—The diorites mostly occur as dykes and intrusive sheets; the former are usually fine-grained at their margins and coarsely crystalline-granular towards the middle of the dykes. The intrusive sheets are sometimes of considerable extent, and follow more or less closely the planes of stratification of the rocks, usually crystalline schists, gneiss, etc., into which they have been intruded. Veins of diorite are occasionally to be seen breaking through granite. Diorites are generally more or less irregularly jointed, but, in some instances, a rude columnar structure is developed. Sometimes the diorites show a concentric spheroidal structure, when weathered. Passages between quartz-diorites, mica-diorites, etc., may occasionally be seen, and the different varieties appear to be mere local differentiations of the same rock.

Diorites may be eruptive and metamorphic. The latter sometimes resembles the former, and has been taken both for diorite and granite; usually it bears some resemblance to augite andesite or basalt. The diorites of the Comstock Lode contain hornblende, originally colorless but changed by absorption of water to an intense green. The eruptive diorite is sometimes granular, sometimes porphyritic; in the latter, mica predominates, sometimes, over hornblende; quartz is irregularly distributed through the rock. In the granular diorite the hornblende is sometimes green and fibrous, sometimes brown and solid; in the porphyritic varieties the fresh hornblende is always brown and well developed feldspars are rare. Some of the porphyritic diorites have been called *propylite;* some of the fresher porphyritic varieties, *andesite.**

INTERMEDIATE CRYPTO-CRYSTALLINE SUB-CLASS.

These rocks are compounds, fine-grained to compact, of a feldspar with hornblende, pyroxene, nepheline, mica, quartz and some magnetite, nosite and haüyne.

Sp. Gr. . . . . 2.4—3.1
Contains silica, . . 50—67 p. c.

The rocks in this sub-class may be still further divided, according to the texture of the mass, into,

a. Those whose mass is generally fine crystalline-granular and seldom, or never, compact with smooth fracture:

b. Those whose mass is generally compact.

a. Under this head are grouped a number of species that are mentioned as separate rocks because they are quite generally accepted as definite compounds. The latest discoveries in the Comstock Lode seem, however, to show that they are states of other rocks described elsewhere, and that the variation in silica may be due to the conditions under which they solidified, after the analogy of the change from *basalt* to *tachylite* by a sudden cooling. They are all volcanic rocks and are allied to the modern lavas, exhibiting vescicular states. Their principal mass, even under the microscope is granular.

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* Becker's Rept. U. S. Geol. Surv. VIII, 1880–1.

ANDESITE GROUP.

ANDESITE (HORNBLENDE ANDESITE).

A fine grained to compact, and sometimes sub-vitreous principal mass, usually of dark-gray to black color, containing crystals of a triclinic feldspar (andesite, oligoclase, or sometimes labradorite) and sanidine, hornblende, and some magnetite.

Sp. Gr.	2.6—2.7
Contains silica, . .	55—62 p. c.

The name *andesite* is, for brevity, applied to the variety containing hornblende, although it is generally described as *hornblende-andesite.* The triclinic feldspars are the most predominant in this rock and sanidine exists only in small amounts. As accessories biotite and magnetite are quite plentiful; augite and nepheline sometimes occur; haüyne and olivine are rarely present. These rocks are more or less porous and are frequently granitoid. This may be taken as a diorite that has solidified quickly.

DACITE (QUARTZ-ANDESITE).

An andesite containing quartz in crystals or granules; seldom in the matrix.

Sp. Gr.	2.6—2.7
Contains silica, . .	60—72 p. c.

The hornblende is frequently in small well-developed crystals, which sometimes show twinning. Olivine never occurs. Sometimes biotite exists in such abundance as to make a variety called *biotite-dacite.* Some of these rocks in Hungary may be considered as rhyolites with triclinic feldspars in the place of sanidine. This may be taken as a quickly-solidified quartz-diorite.

AUGITE ANDESITE.

A finely crystalline principal mass consisting of oligoclase or andesite, augite and magnetite.

Sp. Gr.	2.7—2.8
Contains silica, . .	57—62 p. c.

The matrix is of a brownish-gray or black color. This differs from basalt by containing oligoclase. In some rare cases it contains quartz, and such species are called *quartz-augite-andesites.* Olivine frequently occurs in such quantities as to constitute an *olivine-andesite.* A variety containing *diallage,* and resembling euphotide, is called *ophite* and, when this contains oligoclase in abundance, it is called *oligoclase-ophite.*

PROPYLITE.

A fine crystalline-granular compound of oligoclase and a light green mineral; generally weathered.

Sp. Gr.	2.7—2.9
Contains silica, . .	57—62 p. c.

This is the country rock of the Comstock Lode, and there is a great difference of opinion as to whether it be a distinct rock or not. The latest developments seem to show that it is a weathered mixture of oligoclase and augite or hornblende, and is therefore analogous to the andesites or the diorites. The microscope shows that the greenish mineral has in many cases undergone two alterations: the center will be pyroxene; then will come a ring of hornblende, and this will be surrounded by epidote. The majority of the greenish mineral is epidote of a vivid yellow tinged with pale green. It occurs in crystals, fibers and rounded grains. The whole rock is soft from weathering. The addition of quartz forms the species *quartz propylite*. These are equivalent to the *greenstone-trachytes* of Von Richthofen.

TRACHYDOLERITE.

A fine-grained compound of oligoclase or labradorite with hornblende or pyroxene, some magnetite, and frequently some mica. These minerals occur in a gray or brown matrix.

Sp. Gr.	2.7—2.8
Contains silica, . .	54—61 p. c.

This may be taken as a volcanic rock, intermediate between trachyte and dolerite. It is frequently vescicular and occurs at the Peak of Teneriffe, in Italy and elsewhere. Some of the varieties contain more pyroxene and shade into dolerite.

B. These rocks have generally a smooth fracture, and principal mass is seldom granular.

MELAPHYRE. Trap in Part.

A compact, porphyritic, vescicular, or amygdaloidal compound of plagioclase, augite, olivine, magnetite or titanite, and delessite or chlorophaeite; generally black, greenish-black, or brownish-black.

Sp. Gr.	2.6—3.1
Contains silica, . .	54—62 p. c.
Hardness, . . .	5.6

The melaphyres are obscure rocks allied to the basalts and only distinguished from them by the alteration products, *delessite* (a ferruginous chlorite) and *chlorophœite* (a hydrous silicate of the protoxide of iron, and by the fact that the amygdaloidal cavities are filled with agate, amethyst, and chalcedony, *rarely with the zeolites.* They are generally of palaeozoic age. The Oberstein amygdaloid, famed for its agates, is included here. Under this head are included, by some, the varieties:

A. *Labrador Porphyry.*

A greenish-gray or blackish paste, fusible with difficulty, often containing calcite and large crystals of labradorite.

Sp. Gr.	2.77
Contains silica, . .	54 p. c.

This contains 2.5 per cent. of water.

B. *Uralite Porphyry.*

A greenish-gray or blackish-green matrix containing blackish-green or brown crystals of uralite.

PHONOLITE GROUP.

PHONOLITE, CLINKSTONE.

A compact matrix of sanidine (or oligoclase) and nepheline, with hornblende, leucite, nosite, and *some magnetite or titanite; in its fresh state dark greenish gray or yellowish, showing single cleavage surfaces of sanidine. The mass is, as a rule, somewhat slaty or schistose, or of thin tabular jointed structure—gives, under certain conditions, a clear sound when struck with a hammer (whence the name); on weathering, a sharply defined yellowish-white or white crust is formed.*

Sp. Gr.	2.4—2.6
Contains silica, . .	50—62 p. c.

The ringing sound is observed in thin slabs. The constituent minerals of phonolite are sanidine, nepheline, and generally more or less hornblende and magnetite. Nosite and haüyne are often present in considerable quantity, also leucite and sometimes tridymite. The minerals which are less common, and less important as constituents of phonolite, are augite, olivine, sphene, zircon, apatite, and titaniferous iron. Oligoclase as well as sanidine phonolites are so closely related to the trachytes that they have received the name of trachy-phonolite. The matrix or ground-mass of phonolite is micro-crystalline, and presents either a rough and porous, or a compact character. It is partly soluble in hydrochloric acid, the soluble portion being represented by nepheline and zeolitic decomposition products of that mineral, while the felspathic portion of the matrix constitutes the insoluble part. The smaller the percentage of the insoluble matter, the higher, as a rule, is the percentage of water which the rock contains, and this is usually accompanied by an increase in its specific gravity. The larger the percentage of silica which a phonolite contains, the less, as a rule, is its percentage of soluble material. The phonolites fuse easily, before the blowpipe, to a whitish or greenish glass, and yield more or less water when heated.

The sanidine is very commonly twinned on the Carlsbad type, and is frequently more or less altered. Plagioclastic feldspars are only of exceptional occurrence in phonolites. The nepheline crystals, although they occasionally attain moderate dimensions, are, as a rule, very minute. In some phonolites they are very numerous; while in others, the mineral is so poorly represented, that the rocks approximate to trachytes. Haüyne is often very plentiful, and there are few phonolites in which it is totally absent, except in those rocks in which leucite takes the place of nepheline.

Phonolite occurs occasionally in the form of lava flows, but more commonly in conical masses or hills. It sometimes exhibits well-marked columnar structure, and has a very general tendency to split into slabs or slates, the more finely-cleavable varieties being used for roofing purposes in certain localities. In advanced stages of weathering the rock passes into an earthy condition, known as phonolite-wackė; all completely kaolinize, with scarcely a trace of their slaty structure; show an earthy fracture, and a light color. By some the cavities in which the zeolites occur are thought to be due, not to gas, but to a corrosive process of decay, as there are comparatively few cavities in a fresh rock. Yet some few phonolites have been found with very decided vescicular cavities.

PORPHYRITE GROUP.

These are distinguished from the Quartz-Porphyries (q. v.) by the absence of quartz from the base and as included crystals.

They contain in a felsitic matrix of a dark, usually a brownish color, individual crystals of feldspar, mica, or hornblende. The matrix is sometimes also vescicular or amygdaloidal.

Sp. Gr.	2.6—2.7
Contains silica, . .	59—61 p. c.

PORPHYRITE.

A felsitic matrix, usually dark-brown, containing crystals of orthoclase or oligoclase, and occasionally other minerals.

Sp. Gr.	2.6—2.7
Contains silica, . .	61 p. c.

The matrix is sometimes gray, red, violet, or blue, and it may contain garnet, titanite, magnetite, etc. The *rhomb-porphyry* of Norway is included here. It is frequently compact, with few crystals, amygdaloidal, and weathered.

HORNBLENDE-PORPHYRITE.

A dark colored felsitic mass containing crystals or crytalline particles of hornblende and oligoclase.

Sp. Gr.	2.6—2.7
Contains silica, . .	59 p. c.

The matrix is the predominant part of this rock and, in its fresh state, is brown, violet-brown or gray; weathers lighter. The hornblende forms small columnar crystals. It is frequently vescicular and amygdaloidal. From the constituent minerals this is sometimes called *diorite-porphyrite*.

A. *Porfido-rosso-antico.*

This is a hornblende-porphyrite containing white feldspar, black acicular crystals of hornblende, and usually some micaceous iron, in a red matrix.

MICA PORPHYRITE.

A matrix similar to the above in composition and color, containing crystals or crystalline particles of mica and feldspar.

Sp. Gr.	2.6—2.8
Contains silica, . .	59 p. c.

The feldspar is orthoclase and oligoclase, and is white, greenish, or reddish; sometimes in thin laminae. The mica is in distinct laminae and is usually biotite. Sometimes hornblende occurs and it passes into *hornblende-porphyrite*, and quartz changes it to *granite porphyry*. Vescicular and amygdaloidal forms occur and it is frequently compact, with few crystals. The amygdaloidal varieties have their cavities filled with green-earth, calcite, and siliceous minerals and thus shade into the *melaphyres*.

MICA-TRAP GROUP.

These are fine-grained compounds of mica and feldspar without a marked porphyritic texture and very seldom contain quartz.

Sp. Gr.	2.5—2.9
Contains silica, . .	50—65 p. c.

MINETTE.

A gray felsitic matrix, containing much blackish-brown magnesia, mica and sometimes distinct crystals of orthoclase and hornblende.

Sp. Gr.	2.5—2.9
Contains silica, . .	50—65 p. c.

The mica is in distinct laminae or scales, never in crystals, and it sometimes is so predominant as to be alone distinctly visible. It shades into *mica porphyrite*. Frequently it is decidedly foliated from the arrangement of mica in parallel planes and, when it occurs with gneiss, may be considered as metamorphic.

A. *Fraidronite.*

A greenish felsite matrix with a greater or less quantity of mica, and some pyrite and quartz.

This is a variety of minette containing calcite and siderite.

KERSANTON.

A blackish-green to greenish-gray, felsitic matrix containing hexagonal tabular crystals of brown or black mica. Sometimes the matrix is granular and contains crystals of oligoclase.

Sp. Gr.	2.6—2.9
Contains silica. . .	53 p. c.

This may be taken as a minette where oligoclase replaces orthoclase. The mica is not only distributed through the matrix, but is a distinct coating round small amygdaloids of calcite or quartz. Marcasite and magnetite occur as accessories. The oligoclase is generally weathered. Kersanton is discolored when treated with HCl. It is used for building purposes in Brittany.

KERSANTITE.

A fibrous or porphyritic compound of oligoclase and mica, frequently containing some hornblende and quartz.

Sp. Gr.	2.5—2.8
Contains silica, . .	64 p. c.

Oligoclase predominates in the matrix, which is sometimes entirely composed of that mineral, sometimes of oligoclase and mica. The oligoclase is white or greenish, tinged with red by decomposition; the biotite is in dark laminae; the quartz in small grains. In some cases it is amygdaloidal and the cavities are filled with quartz, chlorite, epidote, and calcite. The porphyritic varieties of this rock shade into the *mica porphyrites* on the one hand and toward *granite porphyry* on the other, It differs from Kersanton only by containing hornblende and a greater amount of quartz. It is of limited extent only.

BASIC CRYSTALLINE ROCKS.

These are compounds of a triclinic feldspar with hornblende, pyroxene, or hypersthene, and generally some magnetite.

Sp. Gr.	2.2—3.1
Contains silica, . .	40—58 p. c.

These may be separated into two classes, as before, depending upon the size of the crystals in the matrix.

BASIC CRYSTALLINE-GRANULAR SUB-CLASS.

DOLERITE GROUP.

DOLERITE.

A crystalline-granular compound of labradorite, pyroxene, and a small amount of magnetite.

Sp. Gr.	2.7—3
Contains silica, . .	42—57 p. c.

This rock is generally granitoid in texture so that the individual minerals can be readily distinguished. The labradorite occurs in clear gray depressed crystals, sometimes white; and the pyroxene, sometimes in black columnar crystals, sometimes in thin bladed ones. In addition, there is usually a matrix composed of the same ingredients with magnetite and some siderite and calcite. In some dolerites the labradorite is partly replaced by oligoclase and anorthite. A fresh fracture shows a very brilliant surface. The fine crystalline-granular variety is called *anamesite*. Besides the above minerals there are a number that frequently occur in such quantities as to become essentials. Nepheline, leucite and haüyne replace the feldspar; olivine, bronzite, and zeolite also occur in considerable amount. The olivine sometimes appears in tolerably well-defined crystals; but it is more usually in roundish grains, or in granular aggregates. The latter are sometimes of considerable size, and occasionally show, in external configuration, that they are large, rudely-developed crystals. Dolerite occurs porphyritic, vescicular, scoriaceous, amygdaloidal, and weathered. When it becomes compact it passes into *basalt*, (q. v.) Some authors regard the dolerites as post-tertiary *melaphyrs* and *diabases*.

NEPHELINE-DOLERITE.

A crystalline-granular compound of nepheline, pyroxene, a little magnetite, or titanite, and more or less olivine.

Sp. Gr.	2.2—2.6
Contains silica, . . .	41—51 p. c.

This is a dolerite where nepheline has replaced the feldspar. As accessories it contains apatite, sphene, haüyne, garnet, leucite, sodalite, and sanidine. *Nepheline-dolerite* is porphyritic, vescicular and amygdaloidal, and, when compact, passes into *nepheline basalt*, which can hardly be distinguished from common basalt.

A. *Analcymite.*

A nepheline-dolerite in which the nepheline is almost entirely replaced by analcite, which fills clefts and cavities.

In this rock two-thirds of the mass is analcite. This is of limited extent.

LEUCITOPHYR.

A grayish compound of leucite, pyroxene, and magnetite, containing crystals of the component minerals.

Sp. Gr.	2.5—2.9
Contains silica, . .	45—54 p. c.

This is a dolerite where leucite replaces the feldspar. Leucite is the predominant mineral. The color of the mass is more gray or reddish-gray than dolerite or basalt. The distinct crystals of leucite are always porphyritically imbedded and never occur in geodes. As accessories occur biotite, sodalite, sanidine, labradorite, nepheline, olivine, haüyne, garnet, and traces of apatite. Leucitophyr forms old and recent lavas of Vesuvius. It occurs vescicular and amygdaloidal and, when compact, becomes *leucite-basalt.* Some of the *leucite-sanidine* lavas are classed with the *trachytes.*

HAÜYNOPHYR.

A deep gray or blackish compound of haüyne and pyroxene.

Sp. Gr.	2.5—2.8
Contains silica, . .	40—50 p. c.

It is generally fine-grained. The haüyne is in blue crystals and replaces the feldspar of dolerite; sometimes it is red, or red with a blue border from laminae of hematite; sometimes it is grayish or colorless. It is frequently porphyritic from the development of haüyne and pyroxene crystals. Haüynophyr generally contains leucite, nepheline, with usually some olivine and apatite; there is no feldspar. The rock is of limited occurrence in the Eifel and near Naples. The compact variety is called *haüyne-basalt*, and is more common than the fine-grained varieties.

DIABASE GROUP.

DIABASE.

A crystalline-granular compound of oligoclase, or labradorite, albite, and anorthite, with pyroxene and some viridite; in its fresh state it is dark green.

Sp. Gr.	2.7—2.9
Contains silica, . .	43—56 p. c.

This rock is called by Dana and others a pre-tertiary dolerite, and the only distinction between the two is the green color due to the presence of viridite which is an alteration product. Some of these rocks contain quartz and seem to disprove the theory of Breithaupt that quartz and pyroxene mutually excluded one another. The question may be solved in the future by the discovery that the pyroxene in all such rocks has been altered from hornblende, as under the microscope, the ground mass of diabase is generally partially decomposed. The greenish mineral (viridite) is not chlorite, as it is more easily soluble in hydrochloric acid. It has been called epichlorite by some; viridite or chloritic matter, by others, and results from the alteration of the pyroxene which it completely replaces at times, so that the crystal is a pseudomorph after pyroxene. As accessories occur apatite, calcite, biotite, magnetite, pyrite and chalcopyrite. The amygdaloidal varieties contain, in the cavities, quartz, actinolite, asbestus, pistacite, cats-eye, axinite, calcite, dolomite, etc. Diabase is generally fine-grained; it is also porphyritic, slaty and amygdaloidal. The amygdaloidal cavities are always filled, which shows that the rock has lain for some time under hydroplutonic agencies. The compact variety is called *aphanite, and bears the same relation to diabase that basalt does to dolerite.*

A. *Calcareous Diabase.*

A fine grained diabase containing small rounded grains of calcite which do not appear to be the filling up of amygdaloidal cavities.

When compact this is called *calcareous-aphanite,* and, when slaty, *schalstein.*

EUKRITE.

A crystalline-granular compound of anorthite and grayish-green pyroxene, with occasionally some olivine, hornblende, and epidote.

Sp. Gr.	2.7—2.8
Contains silica, . .	47 p. c.

It is of limited occurrence in Moravia and Ireland. The epidote seems to be the result of alteration. The anorthite is white and entirely soluble in hydrochloric acid.

GABBRO GROUP.

These rocks are generally crystalline-granular compounds of labradorite and diallage.

Sp. Gr.	2.8—3.2
Contains silica, . .	43—50 p. c.

Labradorite is replaced by saussurite, or partially by olivine, and diallage by hypersthene or smaragdite, and sometimes enstatite or bronzite. As accessories occur mica, augite, hornblende, talc, serpentine, calcite, pyrite, garnet and, occasionally, quartz. When compact these rocks pass into *aphanite.*

GABBRO, DIALLAGE ROCK, GRANITONE.

A crystalline-granular compound of labradorite and diallage.

The labradorite is coarse or fine grained, and white, greenish-gray, or violet; the diallage is in tablets or laminae of sub-metallic luster and of a copper-brown, or olive-green color; often very fibrous. As accesories occur the minerals mentioned under the general group. Gabbro generally occurs massive. If the rock has been much weathered, the diallage is in relief.

EUPHOTIDE.

A compound of saussurite and diallage or smaragdite, with titanite or chromite, pyrite, serpentine, and carbonates.

Sp. Gr.	2.65—3.36
Contains silica, . .	43—50 p. c.

The composition of this rock has been a subject of dispute. It is unfortunate that the name has been given to two rocks of very different compositions:

a.—*A grayish-white, greenish, or sometimes violet compound that fuses at 3—3.5 and is attacked by acids.*

Sp. Gr.	3.65
Contains silica, . .	43—44 p. c.

This rock is the *euphotide* of Mont Rosa and is a compound of the original *saussurite* (*Saussure's jade*) and diallage or smaragdite. Hunt has showed that saussurite is a compact lime-soda zoisite. This differs from,

b.—*A grayish-white or white tenacious compound of a compact feldspar* (*labradorite*) *and smaragdite.*

Sp. Gr.	2.5—2.6
Contains silica, . .	50 p. c.

To this compact feldspar the name of *saussurite* was given, as it was to a number of other minerals of a compact nature. This rock fuses at about the same temperature as (a), and is more easily attacked by acids. This is the *euphotide* of Delesse and the French geologists.

NORITE.

A compound of hypersthene or diallage and feldspar (*labradorite or orthoclase* [*with soda in small amount*]), *and even some quartz.*

Sp. Gr.	2.9—3.1
Contains silica, . .	45 p. c.

The feldspar is the predominant ingredient in this rock and frequently the whole mass is a granular feldspar. In some cases the hypersthene is replaced by enstatite and bronzite. When it occurs with magnetite, the latter is generally titaniferous. It occurs in Norway, New York and other parts of North America.

HYPERITE (HYPERSTHENITE).

A generally coarse-grained compound of labradorite and hypersthene (bronzite or enstatite).

Sp. Gr.	2.9—3.1
Contains silica, . .	43—45 p. c.

The labradorite is coarse to fine grained, gray, bluish, or greenish. The hypersthene is dark-brown to green on a cleavage surface, with metallic pearly luster. The labradorite weathers the more readily and leaves the hypersthene protruding. As accessories occur titanite, garnet, hornblende, olivine, brown mica, apatite, and pyrite.

A. *Monzonite (Monzoni-Hypersthenite).*

A variety of the above, from Monzoni in the Tyrol, containing greenish-white labradorite and dark-green to black hypersthene. The hypersthene predominates generally.

In some cases the labradorite predominates and, in such cases there are crystals of dark-brown mica and common black pyroxene.

OLIVINE GABBRO.

A variety of hyperite containing olivine: color black.

Sp. Gr.	2.9—3
Contains silica, . .	48—50 p. c.

In this rock olivine is generally the predominant mineral. It generally contains a large per cent. of iron and is easily fusible. It is distinguished by its peculiar luster and fracture, and shows abundant cleavages.

BASIC CRYPTO-CRYSTALLINE SUB-CLASS.

BASALT GROUP.

BASALT. Trap in part.

A fine-grained or compact compound of labradorite or nepheline, leucite, haüyne, and oligoclase, pyroxene, with some magnetite. In the fresh state, black or dark gray.

Sp. Gr.	2.3—3.1
Contains silica, . .	40—50 p. c.

The mineral ingredients are too small to be recognized by the naked eye. It may be taken as the compact state of the *dolerites*, pp. 79–82, and we may have the varieties.

A. *Basalt.*

This rock is generally black, sometimes gray; dull conchoidal fracture; either massive or containing (porphyritically) crystals or grains of olivine, labradorite, augite, mica, and magnetite.

Sp. Gr.	2.9—3.1
Contains silica, . .	40—56 p. c.

This is vescicular, scoriaceous, amygdaloidal, porphyritic and weathered. The amygdaloidal varieties contain calcite or a lime zeolite in the cavities, and thus indicate the decomposition of labradorite.

B. *Nepheline-Basalt.*

A rock similar to (A), of conchoidal fracture; more greasy luster, and lighter color than basalt; containing crystals of nepheline, leucite, haüyne, sanidine, and sodalite.

Sp. Gr.	2.3—2,7
Contains silica, . .	41—51 p. c.

This has states similar to basalt, but the cavities of the amygdaloidal states are filled with soda or potash zeolites, *e. g.*, analcite.

C. *Leucite-Tephrite.*

A compact leucitophyr; of grayish white color, and consisting almost entirely of leucite.

Sp. Gr.	2.6—2.9
Contains silica, . .	45—54 p. c.

Although to the naked eye it may appear compact, under the microscope it is an aggregate of leucite crystals or grains touching one another. Biotite, olivine, and sanidine frequently occur as accessories.

D. *Nosite-Melanite Tephrite.*

A fine-grained or compact compound of nosite, sanidine, black garnet (melanite), with some hornblende, pyroxene and titanite.

Sp. Gr.	2.7—2.9
Contains silica, . .	48—55 p. c.

This is a dark grayish rock that frequently shows hyalite crusts, from the decomposition of the silicates it contains.

E. *Mica-Basalt.*

A variety of basalt rich in mica.

This is merely a state of basalt and hardly worthy of a separate name, as mica exists to a greater or less extent in all basalts.

F. *Haüyne-Basalt.*

A compact haüynophyr.

Of a porous, vescicular nature and distinguished by the haüyne crystals. Haüyne-basalt is a rock of limited occurrence.

The basalts occur in lava streams, plugs, intrusive sheets, and dykes. They are of frequent occurrence in the Jura-Trias formation of the Eastern United States. East and West Rock, near New Haven, Bergen Hill and the Palisades of the Hudson, the Table mountains of California are examples. They are often traversed by structural planes which are, in some cases, so disposed that the rock assumes a columnar character, as near Orange, N. J., on the Columbia River, Oregon, at the Giant's Causeway, Fingal's Cave, and at many foreign localities. The columns are occasionally curved. They sometimes stand in vertical, at others in horizontal or inclined positions, which, in all cases, are directed at right angles to the surfaces upon which the rock cooled. This columnar structure is caused by the contraction of the basalt on cooling, but it is not exclusively in basalts that it occurs; it is occasionally to be met with in trachytes, phonolites, pitchstones, felstones, also in argillaceous rocks at their contact with eruptive masses. Sometimes a platy or tabular structure is developed in basalt, especially near the margins of intrusive plugs or dykes. Spheroidal structure also occurs in these rocks, and the spheroids or balls may be seen often closely packed between the divisional planes which constitute the boundaries of the columns. The columns are sometimes divided by cup-like joints, so that one portion of the column is convex and fits into a concave surface on the adjacent part of the column. The number of sides which basalt columns present, varies. Occasionally they have only three sides, at other times five, six, or eight. The plugs, mentioned above, are the filled-up flues of a former volcano. The vitreous conditions of basalt have been already described under the head of tachylyte. Basalts often assume a vescicular character, which is generally most prevalent at and near the upper and the lower parts of the lava streams. The vescicles, when subsequently filled with calcite, zeolites, and other minerals of secondary origin, render the rock amygdaloidal.

APHANITE GROUP.

APHANITE.

A compact, apparently homogeneous mass, usually dark green to black; about the hardness of feldspar; of dull sub-conchoidal fracture; sometimes porphyritic by reason of crystals of feldspar, hornblende, or pyroxene; also vescicular, amygdaloidal, and slaty.

Sp. Gr.	2.6—2.9
Contains silica, . . .	43—58 p. c.

This may be taken as a compact diabase, diorite, or gabbro, and, as these are generally pre-tertiary rocks, it may be taken as a pre-tertiary basalt. No attempt will be made to distinguish diabase-aphanites from the aphanitic forms of the other rocks mentioned above. In general, aphanite may be distinguished from basalt by its color, though some aphanites are black. There are a number of varieties in texture and structure.

A. *Calcareous Aphanite (Kalkaphanite).*

An aphanite containing grains of calcite or dolomite which are not due to the filling of amygdaloidal cavities.

This is an aphanitic *calcareous diabase.* The mass is compact and slaty.

B. *Variolite.*

An aphanite containing greenish or violet-gray concretions of a stringy, radiated, or concentric texture, from the size of a pin-head to that of a walnut, firmly grown in, and not sharply defined.

Sp. Gr.	2.9
Contains silica, . .	56 p. c.

These pustular projections are composed of labradorite and pistacite, and in this respect the rock differs from (*A*). As accessories occur pyrite and magnetite in the matrix, and quartz, pistacite, calcite and viridite in the cavities.

C. *Black Porphyry, Labradorite-Porphyrite.*

A black matrix enclosing crystals of labradorite and small particles of viridite.

Sp. Gr.	2.7
Contains silica, . .	56—58 p. c.

The labradorite is in dull-green crystals. As accessories occur brownish-black plates of mica, pyrite, and magnetite.

D. *Oligoclase-Porphyrite.*

A compact, dark-green aphanite containing crystals of oligoclase.

To this belongs much of the *porfido-verde-antico.*

E. *Augite-Porphyrite.*

A compact, dark-green aphanite containing crystals of augite.

With the augite crystals are sometimes those of labradorite. They occur vescicular and amygdaloidal.

The aphanites are usually of a jointed structure, or very distinctly cleft; generally the blocks are massive, sometimes they are columnar, like the basalts, or irregularly spherical. They accompany diabase, gabbro, and diorite, and are so connected with the masses of the latter as to suggest the idea of a more rapid cooling, as they occur in narrower dykes.

CHAPTER III.

SEDIMENTARY ROCKS.

These are the results of the deposition of material under water. When such material was heterogeneous and the cause of deposit intermittent, they are stratified, or their beds lie above one another in parallel planes. The great majority of such deposits consist in the comminuted fragments of older rocks. A few are the results of chemical precipitation, or the gathering of organic material. As they are all *clastic* or *fragmental*, there is rarely a crystalline texture, except in the second class just mentioned. Sedimentary rocks are

a. Mechanical deposits;
b. Chemical precipitates;
c. Organic aggregations.

The predominant minerals are the stable compounds, *i. e.*, those not easily weathered, as quartz, calcite and dolomite. The feldspars that predominate in the primary rocks are kaolinized and reduced to clay; the other silicates are separated into more stable compounds; the rocks weather and crumble under the action of the atmospheric agents till quartz and the clays are the final results.

It is customary to separate from the sedimentary rocks those coarse aggregations whose particles have been so bulky as never to have been held in suspension. This division results in the two groups:

SEDIMENTARY ROCKS (*proper*), *whose particles were fine enough to have been held in suspension mechanically or by solution, and which have been deposited by a loss of motion in the suspending element* (*mechanical precipitation*), *or by its concentration* (*chemical precipitation*)*; as the clays, marls and limestones;*

FRAGMENTAL ROCKS, *whose particles were so coarse and heavy that they have never been held in suspension, but have been only distributed or collected by rapid currents; as sandstones and conglomerates.*

SEDIMENTARY CLASS.

ARGILLACEOUS GROUP.

CLAY and LOAM.

These are earthy deposits chiefly consisting of clay, and when moist are more or less plastic.

Contains silica . . . 40—75 p.c.

The clays are plastic when moist, but lose this property on drying or under great pressure. Dry clays, when breathed upon, gives a peculiar and characteristic odor. Pure clay is white; iron colors it brown or yellow; much sand or silica converts it to *fire-clay.*

CLAYSTONE and HARDENED CLAY.

A compact and tolerably solid mass, consisting of clay, not slaty, with earthy fracture; variously colored.

This is sometimes the result of the weathering of a felsitic rock, and is distinguished from the sedimentary claystones by the absence of stratification and a variety of colors. Such unstratified claystones are classed as *Tuffs* (*q. v.*).

SHALE.

A laminated clay-rock whose fissile structure is due to its original stratification and not to slaty cleavage. In other respects, similar to clay slate.

Shale and *Clay Slate* pass into one another, and the former is generally the softer and more recent of the two. The color is various. It is found in the coal formation as a top rock, carrying impressions of coal plants.

CLAY SLATE.

A compact, fissile clay rock, with slaty cleavage more or less perfect, as in roofing slate.

Sp. Gr.	2.5—2.8
Contains silica,	40—75 p. c.

The colors of this rock are dull blue-gray, bright red, purple, green or black. It sometimes contains quartz, mica, chlorite, ottrelite, talc, sericite, chiastolite, etc., and sometimes in such abundance as to form a variety.

A. *Novaculite, Whetstone.*

A variety containing a large amount of fine siliceous matter.

In this the slaty cleavage is seldom distinct; generally absent; fracture conchoidal and even splintery. Used for sharpening knives, etc. Occurs in Europe and at Hot Springs, Arkansas.

MARL GROUP.

These are calcareous clays and are transitions between the clays and the limestones. They contain also many of the accessory minerals of the two groups mentioned.

MARL.

A compound of clay and lime, earthy, compact, or fissile; usually soft; crumbles on exposure to air; effervesces with acid.

The proportion of lime varies from 10–50 p. c. The color is generally gray; frequently yellow, brown, red, violet, bluish, or greenish. It may be compact, shaly, or earthy. It may be argillaceous, calcareous, arenaceous, micaceous, bituminous, glauconitic, and gypseus.

A. *Copper Slate.*

A bituminous marl-slate of Thuringia, carrying copper, and other metals.

This is worked at Mansfeld for copper.

LIMESTONE GROUP.

This may consist of an aggregate of broken shells or may result from chemical precipitation. In either case the texture and structure will vary. In many cases metamorphic action has destroyed the original structure and texture. It is hard to distinguish by the naked eye the origin of the members of this group and so there will be no separation according to origin.

*LIMESTONE.

A crystalline-granular, compact, earthy, or oölitic aggregate of calcite; effervesces strongly with acids; variously colored.

Sp. Gr.	2.6—2.8
Hardness, ...	3.

A. *Granular Limestone, Marble.*

Granular texture; variously colored, usually white.

This may contain many accessory minerals and form the varieties:

a. *Cipolino, rich in mica; slaty texture;* runs into calcareous mica schist.

b. *Ophicalcite, ophiolite. A compound of limestone and serpentine;* granular to compact. Called *Verde Antique.*

c. *Hemitrene. A granular compound of limestone, hornblende and tremolite.*

B. *Compact Limestone.*

Compact; conchoidal or splintery fracture, dull; color generally gray or yellowish, blue, green, red, brown and black.

This may vary in composition so as to be dolomitic, bituminous, argillaceous or marly, ferruginous, siliceous or cherty.

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* The limestones about Bethlehem belong to the calciferous formation and contain a large proportion of sand, as can be seen in the amounts left when lime is slacked for building purposes. The limestone at Catasauqua is a purer carbonate of lime, and that of Coplay is a transition between the Catasauqua limestone and the Slatington slates, and is thus useful for hydraulic cement.

C. *Earthy Limestone. Chalk.*

Rough to the feel; friable; generally white; gives its color to whatever it is rubbed against.

It is also oölitic, nodular, slaty, porous, geodic, cellular, brecciated, and fibrous.

According to the method of formation we may distinguish two other kinds:

D. *Tufa.*

A porous, friable deposit from calcareous springs containing many remains of plants and animals.

Travertine. A compact calc-tuff; hard and semi-crystalline. Occurs in the form of stalagmite and stalactite; also at the mouth of springs.

E. *Shell Limestone.*

Consisting of the broken and consolidated fragments of shells, etc., of various animals. Of all geological periods.

DOLOMITE.

A compound of dolomite similar to limestone.

Sp. Gr.	2.8—2.9
Hardness,	3.5

It is distinguished from limestone by its Sp. Gr., its hardness, and its behavior with acids. It occurs generally under the same states as limestone, but is seldom oölitic, slaty, and fibrous.

GYPSUM.

An aggregate of sulphate of lime containing water, usually crystalline, sometimes compact or fibrous; soft and usually white.

Sp. Gr.	2.3
Hardness,	1.5—2

It is granular, porphyritic, compact, fibrous, sparry, argillaceous, bituminous, and micaceous. Is distinguished from marl, limestone and dolomite by its sulphur reaction; from anhydrite by its containing water.

ANHYDRITE.

A similar aggregate of anhydrous sulphate of lime; white, blue, gray.

Sp. Gr.	2.8—29
Hardness,	3—3.5

Distinguished from dolomite by its not effervescing with acids, and by its sulphur reaction.

FRAGMENTAL GROUP.

SAND.

Usually grains of quartz, sometimes of feldspar, dolomite, calcite, mica, etc.; without a cementing medium.

SANDSTONE, GRITSTONE.

Small grains of some mineral, usually of quartz, cemented together.

When the grains are sharp and angular the variety is called *grit.* Sandstone may be argillaceous, marly, calcareous, ferruginous, talcose, asphaltic.

A. *Arkose.*

With grains of feldspar as well as quartz, and, in some cases, mica. A decomposed granite.

SHINGLE OR GRAVEL.

A loose aggregation of, large and small, rounded pebbles of various rocks, usually quartzose; when large it is shingle; when small and mixed with sand, gravel.

CONGLOMERATE, PUDDINGSTONE.

Pebbles or rounded stones of any mineral or rock firmly cemented together by varying media.

BRECCIA.

Angular fragments of minerals or rocks firmly cemented together.

The above rocks differ only in the *shape* of the fragments. In the breccias they are freshly broken and angular; in the conglomerates, they have been rolled and deprived of their angular nature. In the former the re-solidification has taken place after a greater lapse of time than in the latter. The result is that we find fewer ingredients entering into the construction of conglomerates. The process of rolling and the time necessary to produce such a state, have resulted in the decomposition of many rocks that occur brecciated. The ingredients of the conglomerates are generally quartzose. We may distinguish two kinds of breccias.

A. *Breccia*, (proper).

When the fragments are collected and cemented together by aqueous action.

B. *Friction Breccias.*

Found on the margin of eruptive igneous rocks at the time of their eruption; the matrix of the breccia consists of the substance of the igneous rocks and the enclosed fragments are pieces of the rock broken through.

These occur in the margin of porphyries, aphanites, basalts, trachytes, etc.

C. *Bone Breccia.*

An agglomeration of fractured bones cemented by calcite. Found in caverns.

TUFF.

Accumulations of lapilli, fragments, ash, or other substances, ejected from volcanoes, and more or less firmly compacted together.

The above materials may occur in various states, *e. g.*, rough, earthy, compact, arenaceous, conglomerated or brecciated. According to the varying composition we may have:

Basalt-tuff, conglomerate, and breccia.

Trachyte-tuff, conglomerate and breccia.

Trass or *Pumiceous*-tuff, sand, and conglomerate.

Phonolite-tuff and conglomerate.

We sometimes find, associated with the so-called plutonic rocks, compact claystones that may be due to the kaolinization of the original rocks, or to tuff-formations similar to those of the volcanic rocks. These are sometimes called,

Porphyry or Felsite-tuff.

Greenstone-tuff, conglomerate, and breccia.

CHAPTER IV.

THE METAMORPHIC SCHISTS.

ACID SERIES.

These are more or less foliated, crystalline-granular compounds of quartz, feldspar, or mica, with other minerals as accessories; coarse or fine-grained, compact, or fissile; variously colored.

FELDSPAR GROUP.

GNEISS.

A foliated, crystalline-granular compound of quartz, feldspar, and mica; a foliated granite.

Sp. Gr.	2.6—2.7
Contains silica, . .	64—76 p. c.

In gneiss there are the usual variations in composition as in granite (*q. v.*), and nearly the same accessories are found. The quartz is in lenticular grains; the mica is generally muscovite; the feldspar is usually orthoclase (white in gray gneiss, pink or flesh-colored in red gneiss). Gneiss occurs coarse to fine-grained, porphyritic, slaty, granitic. In the last the foliation is nearly obliterated. In porphyritic gneiss the orthoclase occurs in large twinned crystals. In some cases the mica occurs in lenticular aggregates, one or two inches in length. Much *hornblende* forms *syenitic* or *hornblendic gneiss*. *Dichroite* frequently replaces mica and forms *dichroite-gneiss*. *Chlorite* or *talc* instead of mica forms *protogine-gneiss*. The rocks of South Mountain, South Bethlehem, Pa., back of the University, are mainly syenitic-gneiss.

A. *Hälleflinta.*

A foliated or unevenly laminated felsite; compact; sometimes with chlorite.

Sp. Gr.	2.5—2.7
Contains silica, . .	71—81 p. c.

This is a metamorphic felsite. It received its name in Sweden, where it occurs extensively. It is associated with granulite and gneiss, into which it passes by transition states.

GRANULITE.

A slightly foliated, crystalline-granular compound of quartz and feldspar, with little or no mica, and with small red garnets and sometimes cyanite as accessories. A gneiss without mica.

Sp. Gr.	2.6—2.7
Contains silica, . .	70—80 p. c.

The feldspar is white, yellow, or red; it is generally orthoclase, sometimes oligoclase. If mica occurs it is usually white. Granulite forms

ERLAN.

A fine-grained to compact, foliated aggregate of quartz, albite, and garnet.

Sp. Gr.	2.8—3.

This rock is of limited extent and is intermediate between granulite and garnet rock.

QUARTZ GROUP.

MICA SCHIST.

A foliated compound of quartz and mica. A gneiss without feldspar; a foliated greisen.

Sp. Gr.	2.7—3.1
Contains silica, . .	69—82 p. c.

This rock is always crystalline and foliated. It varies in the size of the grains and the amount of each essential. Sometimes the quartz almost entirely disappears, sometimes the mica is almost wanting. The most frequent accessories are calcite, tourmaline, chiastolite, beryl, damourite graphite, specular iron and talc. In the definition it is termed a foliated greisen, though as yet there has been found no transition from the one to the other.

A. *Calcareous Mica Schist.*

A fissile, crystalline-granular, aggregate of quartz, mica, and calcite; of varying degrees of coarseness; slightly foliated.

Sp. Gr.	2.6—2.9
Contains silica, . .	50—80 p. c.

This rock is extensively developed in the Green Mountains of New England, especially in Vermont, and is a transition between crystalline limestone and mica schist. When the mica is inconsiderable in quantity and there is no quartz, it is cipolino (p. 97). It frequently contains knots or lenticular aggregations of coarsely crystalline quartz, mica and calcite.

B. *Damourite Schist. Hydro-mica-schist.*

A schistose aggregate of damourite with more or less quartz; of pearly luster and greasy feel.

The mica is in pearly scales, does not contain magnesia, and acts according to the scheme (p. 124). From its greasy feel, this rock was formerly called talc-schist, The soft micaceous schists near the Bethlehems are of this variety.

QUARTZ-SCHIST.

A more or less schistose aggregate of quartz, usually with some mica.

This may be taken as a variety of mica schist when the silica is in excess of 82 p. c. Frequently the mica is entirely wanting and the rock is but slightly foliated or schistose. In such a case it forms what is known as

A. *Quartzite*

A granular aggregate of quartz with little or no signs of foliation: a metamorphic quartz rock.

This is of frequent occurrence in secondary formations. When the grains are crypto-crystalline and there is more or less argillaceous matter, it passes into *novaculite* (p. 95).

B. *Itacolumite, Flexible Sandstone.*

A fine-grained and foliated compound of quartz with some mica, talc, or chlorite. In thin plates it is flexible.

The grains of quartz are bound together by the laminæ of talc, chlorite, or mica. These are arranged in parallel planes and give it a certain amount of flexibility. It is usually yellow, sometimes reddish-white or bluish-gray. As accessories occur micaceous iron, magnetite, martite, native gold, and diamond. When the iron constituents become predominant, it becomes

C. *Itabirite.*

A granular to compact, foliated, compound of quartz, specular iron (micaceous), and magnetite.

As accessories occur talc, chlorite, actinolite, and native gold.

The two latter occur in Brazil as the matrix of the diamond. Itacolumite occurs extensively in Europe, the Urals, and in North Carolina. Itabirite is a transition to the iron ores.

TOURMALINE-SCHIST, TOURMALINE ROCK.

A crystalline compound of quartz and tourmaline, foliated to granular compact.

The prevailing varieties are schistose. It may be taken as a quartz-schist with tourmaline. As accessories occur mica, chlorite, feldspar, cassiterite, and exceptionally, topaz.

A. *Topaz Rock.*

A crystalline-granular, foliated aggregate of quartz, tourmaline, topaz, and lithomarge.

Of limited occurrence. As accessories occur cassiterite, apatite, malachite, and azurite.

BASIC SERIES.

CHLORITE, TALC, AND HORNBLENDE GROUP.

CHLORITE SCHIST.

A schistose aggregate of chlorite and quartz, sometimes with felspar, mica and talc; color greenish and appearance scaly.

Sp. Gr.	2.7—2.8
Contains silica, . .	31—42 p. c.

The coarser varieties consisting of particolored aggregates of chlorite are called *chloritic-gneiss,* while the fine-grained and evenly-cleavable kinds are called chlorite-slate.

A. *Potstone.*

A soft, sectile, greenish-gray aggregate of chlorite, talc, and serpentine. Used in Italy for making cooking pots.

TALC SCHIST.

A schistose aggregate of talc, usually combined with some quartz or sometimes with feldspar, yellowish or greenish color, and soft greasy feel.

Sp. Gr.	2.6—2.8
Contains silica, . .	27—61 p. c.

It contains little quartz. As accessories occur calcite, chlorite, mica, garnet, asbestus, etc.

A. *Pyrophyllite Schist.*

A schistose aggregate of pyrophyllite.

Occurs extensively in North Carolina. Used for slate pencils, etc.

HORNBLENDE SCHIST, HORNBLENDE ROCK.

A schistose or fine-grained to compact aggregate of hornblende, with small quantities of quartz, feldspar, and brown mica, always dark-green to black.

Sp. Gr.	3—3.1
Contains silica, . .	48—54 p. c.

This is usually foliated. It runs into schistose diorite, syenitic gneiss, etc. As accessories occur garnet (in trapezohedra), pistacite, pyrite, magnetite, etc.

A. *Actinolite Schist.*

A fibrous aggregate of actinolite.

ARGILLACEOUS GROUP.

PHYLLITE, ARGILLACEOUS MICA-SCHIST.

A schistose aggregate in which mica is usually to be recognized as the chief ingredient, or in which the peculiar structure of mica rocks is apparent. Sometimes the whole mass is homogeneous, differing only from clay state by its superior luster.

Sp. Gr.	2.6—2.8
Contains silica,	45—74 p. c.

This is a transition between mica-schist and clay-slate. The varieties are *ottrelite-schist*, *chiastolite-schist*, *alum-schist*, and *black-chalk*. The color is usually gray (greenish or bluish), yellowish, reddish, brownish, and violet. The luster varies between pearly, silky, and sub-metallic.

CHAPTER V.

SPECIAL ROCKS.

SERPENTINE GROUP.

SERPENTINE.

A compact rock, dull in fresh fracture, soft, with greasy feel, usually dark-green or brown.

Sp. Gr. . . . . 2.5—2.7

It occurs compact, porphyritic (with crystals of pyrope), slaty, and veined. As accessories occur pyrope, talc, bronzite, chlorite, mica, magnetite, etc.

GARNET-OLIVINE GROUP.

GARNET ROCK.

A crystalline-granular compound of garnet and hornblende, usually with some magnetite.

Sp. Gr. . . . . 3.4—3.5

Sometimes the mass is almost entirely a granular aggregate of the yellow garnet (aplomb); sometimes it contains other minerals. Occurs in Saxony, Bohemia, and as veins in mica-schist.

EKLOGITE, SMARAGDITE ROCK.

A compound of green smaragdite and red garnet. The former occurs as a finely crystalline matrix, usually slaty or fibrous, in which the garnets are porphyritically enclosed.

Sp. Gr. . . . . 3.2—3.5

As accessories occur quartz, cyanite, epidote, etc.

A. *Egeran.*

A crystalline-granular aggregate of idocrase.

This has been sometimes called eklogite. It occurs at Haslan, near Eger.

B. *Cyanite Rock, Disthene Rock.*

A crystalline-granular, bladed aggregate of cyanite and silver-white mica.

As accessories occur garnet and smaragdite. It occurs in mica schist.

EULISITE.

A compound of brownish-red garnet, green pyroxene, and an iron-olivine (fayalite). The latter is predominant.

Of limited extent, in Sweden.

KINZIGITE.

A crystalline compound of garnet, magnesia-mica, and oligoclase, sometimes compact.

The garnet is a manganese-garnet. Iolite, fibrolite and microcline occur as accessories.

LHERZOLITE.

A crystalline-granular aggregate of olivine, enstatite, diopside, and picotite (a black spinel.)

The olivine predominates and is frequently altered to serpentine. It varies in texture from coarse-granular to medium crystalline-granular; the former state is feebly coherent, the latter quite tough. The enstatite is greenish-brown to yellow. Occurs in limestone.

DUNITE.

A crystalline-granular aggregate of olivine and chromite.

It alters to serpentine and leads some to conclude that many serpentines are alteration products of this rock, especially as they are associated with chromite. Named from Mt. Dun, New Zealand. Occurs also in Europe and North Carolina.

CHRYSOLITE ROCK.

A crystalline-granular aggregate of transparent yellow chrysolite.

Sp. Gr. . . . . 3—3.1

Occurs extensively in North Carolina.

COAL GROUP.

This consists of a series showing the method of formation and variation in metamorphosis.

Peat is an aggregate of vegetable growth, loosely compressed.

Brown Coal or *Lignite* is a compact and earthy mass, with a sp. gr 1.2—1.5 and 55—75 p. c. of carbon. Both of these are distinguished from the rest of the series by their giving a brown color to a solution of caustic potash and by their pyroligneous odor when burned.

Bituminous Coal is a compact black mass with resinous luster, usually friable; burns with a smoke and long flame; has a sp. gr. 1.3—1.5; generally furnishes a coke.

Anthracite is a compact black mass with vitreous or sub-metallic luster; generally with a conchoidal fracture; burns with a short flame and neither smoke nor smell; does not furnish a coke; sp. gr. 1.5—1.7.

There are gradations between the two last, called *semi-bituminous* and *semi-anthracite* as they partake more of the characteristics of the one or of the other. An interlamination of coal and slate, in fine layers, is called *bone* or *bony coal.*

Graphite or *Plumbago* is a grayish-black aggregate, flaky to compact; soft, with greasy feel; generally inflammable; sp. gr. 1.9—2.2.

GUANO GROUP.

Guano forms earthy accummulations of white, gray, or yellowish-brown color and disagreeable smell. It is the excrement of birds.

Caprolite Beds are composed of the fossil excrement of extinct animals. Found in sedimentary strata and in caverns.

IRON ORES.

These have been described extensively enough in the mineralogy and it may suffice to repeat the principal ores that occur as extensive rocks.

Brown Hematite or *Bog-Iron Ore.* With brown streak.

Red Hematite or *Specular Ore.* With red streak.

Magnetite. A compound of per- and protoxide of iron. Streak generally black; some Canadian varieties have red streaks.

Siderite or *Spathic Iron.* White streak; effervesces with acids.

MINERAL GROUP.

OPAL occurs in various forms and is detected by its solubility in potash.

A. *Sinter.* Stratified incrustations and porous masses from geysers.

B. *Tripoli*. Shell-shaped particles of silica of microscopic size. The skeletons of diatoms or infusoria. Earthy and schistose.

QUARTZ.

The principal varieties worthy of note are common quartz, flint, hornblende, basanite, jasper, and agate.

The other minerals of most importance as rocks are ice, cryolite, rock-salt, enstatite, hornblende, pyroxene, heavy spar, kaolin, manganese-ores, calamine, and pyrites.

PART III.

SCHEME FOR DETERMINING ROCKS.

The specimen will fall under one of the four grand divisions, according to its TEXTURE.

A. *Clastic, Fragmental, or Sedimentary* (part). p. 117.
B. *Compact, dull or sub-vitreous.* p. 118.
C. *Compact, vitreous or resinous.* p. 121.
D. *Crystalline or crystalline-granular.* p. 122.

It will then be tested to see under which of the following heads it falls.

I. Untouched or slightly touched by acid.
II. Partly attacked by acids.
III. Completely soluble without effervescence.
IV. Soluble with more, or less effervescence.
V. Burns more or less readily: detonates with KNO_3.

Having determined under which of the above it falls it will then be examined regarding its STRUCTURE, whether it be *a*. Massive; *b*. Stratified or schistose; *c*. Porphyritic; *d*. Vescicular or amygdaloidal.

Turning to the following pages a list of rocks will be found that belong to each group indicated, and the species can be determined by the characteristics there given.

A. CLASTIC OR FRAGMENTAL ROCKS

I. UNTOUCHED BY ACIDS.

a. *Massive or stratified.*

Infusible and insoluble in alkaline solutions.

Conglomerates and breccias of quartz, jasper, the granites, syenites, etc.

Sand, gravel, and shingle.

Sandstone, grit, and arkose.

Soluble in alkaline solutions.

Conglomerates and breccias of opal.

Tripoli and tripoli-slate.

Fusible.

Conglomerates and breccias of felsite, trachyte, pitchstone, rhyolite, the mica-traps, porphyrites, etc.

II. PARTIALLY ATTACKED BY ACIDS.

a. *Massive.*

Infusible or slightly fusible.

Clay and loam, claystone, shale, clay-slate, and the acid tuffs.

Fusible readily.

Conglomerates and breccias of dolerite, basalt, phonolite, gabbro, etc.

The various basic tuffs.

III. COMPLETELY SOLUBLE IN ACIDS WITHOUT EFFERVESCENCE.

a. *Massive or stratified.*

Give water.

Gypsum, and the hydrated iron and manganese ores.

Without water.

Anhydrite, and the anhydrous iron and manganese ores, except siderite.

IV. MORE OR LESS SOLUBLE IN ACIDS WITH EFFERVESCENCE.

a. *Massive or stratified.*

The limestones and dolomites, siderite, marl, travertine, and tufa. Conglomerates and breccias of the above, and bone-breccia.

V. BURN MORE OR LESS READILY.

a. *Massive or schistose.*

The coal series.

B. COMPACT: DULL OR WITH FEEBLE LUSTER.

I. UNTOUCHED BY ACIDS.

a. *Massive.*

Infusible: insoluble in potash lye, density 2.6.

Chalcedony, jasper, basanite, and other cryptocrystalline varieties of quartz.

Density 2.9 or above.

Euphotide (the variety containing Saussure's jade from Monte Rosa. pp. 84, 85.)

Soluble in potash lye.

Semi-opal, siliceous-sinter, and other crypto-crystalline forms of opal.

Fusible.

Compact mass and hardness 6. (Felsite, p. 58); fine grained or crypto-crystalline mass. (The compact states of the porphyrites, pp. 75–77.)

b. *Stratified or schistose.*

Fusible.

Porphyritic. (Slaty-porphyry, p. 61); not porphyritic. (Hälleflinta, p. 103.)

Infusible.

Novaculite. (p. 95.)

c. *Pophyritic.*

With quartz. (Quartz Porphyry, p. 60); with quartz, feldspar, and mica. (Granite Porphyry, p. 59); without quartz. (Feldspar, mica, and hornblende porphyrite, p. 76.)

II. PARTIALLY ATTACKED BY ACIDS.

a. *Massive, schistose, porphyritic, and amygdaloidal.*

Infusible or slightly fusible.

Gray mass with crystals of leucite and augite. (Leucitophyr, p. 81.)

Reddish or grayish, porous mass, with bluish crystals of haüyne. (Haüynophyr, p. 81.)

Easily fusible.

Color green rather than black, decolorized by HCl. (Aphanite group, pp. 90–92.)

Mass like the above with grains, globules or pustules of a hardness of 6. fusible. (Variolite, p. 91.)

Bluish or grayish-black mass, frequently with olivine, seldom containing quartz, more commonly calcite or zeolites, in amygdaloidal cavities, fuses to black globule, density generally less than 3 or over. (Basalt, p. 87.)

Compact mass, black on fresh fracture, weathers reddish, fusible to bottle-green globule, never with olivine, frequently with quartz in amygdaloids, density generally less than 3. (Melaphyre, p. 73.)

Compact, sub-vitreous mass, fusible easily to black globule, more soluble after fusion than before. (Nosite-Melanite-Tephrite, p. 88.)

Compact, sub-greasy mass, smooth fracture, gray color, density 2.6, easily fusible. (Nepheline-Basalt, p. 87.)

Compact, dull, greenish mass, fusible to white globule, yields water when heated, gelatinizes in HCl, with sanidine in crystals. (Phonolite, p. 73.)

III. COMPLETELY SOLUBLE WITHOUT EFFERVESCENCE.

a. *Massive, stratified, and sometimes porphyritic.*

Give water.

Hardness 1.5-2, give sulphur and lime. (Gypsum, p. 98.)

Hardness 3-4, rarely 5, green, red, brown, sometimes is porphyritic from crystals of garnet, blackens before the blowpipe and fuses with difficulty. (Serpentine, p. 109.)

Give iron or manganese reaction, density 3.5—4.5. Hydrous ores of iron and manganese.

Give no water.

Give sulphur and lime. (Anhydrite, p. 99.)

Give iron or manganese reaction, density 4.5—5.5. (Anhydrous ores of iron or manganese.)

IV. MORE OR LESS SOLUBLE WITH EFFERVESCENCE.

a. *Massive and stratified.*

Hardness under 3, infusible.

Some limestones, dolomites, and calcareous clay slates.

A mixture of calcite and serpentine. (Ophiolite, p. 97.)

Hardness over 3, fusible.

Green color. (Kalkaphanite, p. 90.)

C. COMPACT, VITREOUS OR RESINOUS.

I. UNTOUCHED OR SLIGHTLY TOUCHED BY ACIDS.

a. *Massive, schistose, and sometimes porphyritic.*

Infusible, soluble in potash lye, never porphyritic. (Opal, Siliceous Sinter.)

Fusible.

Conchoidal fracture, fusible to a blebby globule. (Obsidian, p. 44.)

Pearly luster, splintery fracture, gives water in the open tube, frequently containing round grains. (Perlite, p. 44.)

Resinous luster, conchoidal fracture, fuses without intumescence to a white, vescicular glass. (Pitchstone, p. 45); with balls of felsite, or crystals or grains of feldspar, and quartz. (Pitchstone Porphyry, p. 45.)

Mass, porous, perlitic, sometimes slaty, with crystals of sanidine, mica or quartz. (Liparite, Quartz-Trachyte, p. 54.)

b. *Vescicular, scoriaceous, pumiceous.*

Perlite and Obsidian occur in the first two states; when in the third, the rock is called (Pumice, p. 44).

II. DECOMPOSED BY ACIDS.

a. *Massive and vescicular.*

Dark mass, fusible to black slaggy globule, heavier than pitchstone, obsidian or perlite. (Tachylite, p. 46.)

D. CRYSTALLINE OR CRYSTALLINE-GRANULAR.

I. UNTOUCHED, OR SLIGHTLY TOUCHED, BY ACIDS.

a. *Massive, and frequently porphyritic.*

Coarse crystalline granular or granitoid.

Quartz, orthoclase, and mica. (Granite, p. 47); with mica replaced by talc or chlorite. (Protogine, p. 49); by tourmaline. (Tourmaline Granite); with tourmaline abundant and flesh-red orthoclase.

(Luxullian, p. 50); mica replaced by epidote. (Epidote-Granite); by iolite. (Cordierite Granite, p. 50); by hornblende. (Syenitic Granite, p. 49.)

With the quartz arranged in layers on the cleavage planes of the orthoclase and white mica. (Graphic Granite, p. 49.)

Like the last but more coarse and irregular. (Pegmatite, p. 49.)

Quartz and orthoclase. (Aplite, p. 50.)

Quartz and lepidolite. (Greisen, p. 51.)

Orthoclase and hornblende. (Syenite, p. 63.)

Oligoclase, and hornblende, greenish appearance. (Diorite, p. 65.)

Oligoclase, hornblende and quartz. (Quartz-Diorite.)

Oligoclase, hornblende, quartz and biotite, fusible. (Tonalite, p. 68.)

Oligoclase, orthoclase, hornblende, mica, and quartz. (Mica-Diorite, p. 67.)

Cyanite and white-mica, with garnets, infusible. (Cyanite Rock, p. 110.)

Mica, garnet and iolite. (Kinzigite, p. 110.)

Garnet and smaragdite. (Eklogite, p. 109.)

Fine crystalline granular.

Rough mass, containing cystals of sanidine and hornblende, density 2.6, mass fusible to colorless glass or enamel. (The Trachyte group, p. 51.)

Grayish mass, containing much magnesian mica in laminae, infusible or slightly fusible. Minette.

Fusible mass, with much magnesian mica in laminae and crystals of hornblende, and oligoclase. (Kersantite, p. 78.)

Reddish mass, hardness 7, attacked by HCl after long heating, density 3.4 to 4.3 (Garnet Rock, p. 109).

Diallage and Saussure's jade (compact zoisite) fusible with difficulty, gelatinizes after fusion. (Euphotide (in part), p. 84.)

Rough porous mass, gray or black with crystals of oligoclase and hornblende. (Andesite, p. 70.)

Like the above, but pyroxene replacing the hornblende. (Augite Andesite, p. 71.)

Grayish, porous, crumbly mass like claystone, oligoclase, hornblende or augite, and dark mica. (Domite from the Puy de Dôme); same composition, undecomposed. (Domite, p. 55.)

b. *Stratified or schistose, and frequently porphyritic.*

Contain feldspar.

Orthoclase or oligoclase, quartz and mica. (Gneiss, p. 102); with talc or chlorite replacing mica. (Protogine Gneiss); with iolite for mica. (Dichroite Gneiss); with hornblende for mica. (Syenitic Gneiss).

Oligoclase and hornblende. (Schistose Diorite, p. 65.)

Orthoclase and black mica, grayish or brownish mass. (Schistose Minette, p. 77.)

Orthoclase and quartz, frequently with garnet and cyanite. (Granulite, p. 103.)

Albite, quartz and garnet. (Erlan, p. 103.)

Without feldspar and with quartz.

Quartz in crystalline-grains. (Quartzite, Quartz Schist, p. 105.)

Quartz and a little white mica, in thin sheets flexible. (Itacolumite, p. 105.)

Quartz and much mica. (Mica Schist, p. 103.)

Quartz and tourmaline. (Tourmaline Schist, p. 106.)

Quartz, tourmaline, and topaz. (Topaz rock, p. 106.)

Quartz, in greater or less amount, and talc. (Talc Schist, p. 107); with pyrophyllite in place of talc and little quartz. (Pyrophyllite Schist, p. 107.)

Quartz and hornblende, sometimes hornblende alone, fusible to black or dark green enamel. (Hornblende Schist, p. 107); an aggregate of actinolite. (Actinolite Schist, p. 107.)

With much argillaceous matter and much mica, quite easily fusible. (Phyllite, p. 108); with ottrelite, (Ottrelite Schist); with chiastolite, (Chiastolite Schist); with decomposed pyrite. (Alum Schist); with carbonaceous matter. (Black chalk.)

c. *Vescicular and amygdaloidal.*

Feldspathic mass, density 2.6, rough and generally more or less fusible. (Vescicular Trachytes, p. 53.)

II. PARTIALLY ATTACKED BY ACIDS.

a. *Massive.*

Pyroxene, white or gray labradorite, or oligoclase, and magnetite. Sp. Gr., 2.9—3; color generally black or gray. When coarse crystalline (Dolerite, p. 79); when fine crystalline, (Anamesite, p. 80.)

Pyroxene, labradorite, or oligoclase, viridite and magnetite; color greenish. (Diabase, p. 82.)

Pyroxene and nepheline; greasy luster; Sp. Gr., 2.6. (Nepheline-dolerite, p. 80.)

Pyroxene and leucite, the latter in rounded, indistinct crystals. (Leucitophyr, p. 81.)

Pyroxene and haüyne with olivine, mica, and leucite; porous; brownish or grayish color. (Haüynophyr, p. 81.)

Pyroxene and hornblende with labradorite and oligoclase, frequently some mica; gray or brown; mass fine crystalline to compact. (Trachydolerite, p. 72.)

Diallage and labradorite; easily fusible; pearly luster. (Gabbro, p. 84.)

Diallage, labradorite and much dark olivine. (Olivine-gabbro, p. 86.)

Much labradorite with diallage; orthoclase and sometimes hypersthene. (Norite, p. 85.)

Hypersthene (more fusible than pyroxene or hornblende) or bronzite and labradorite; coarse crystalline. (Hyperite, p. 86.)

Hypersthene, black pyroxene, dark-brown mica, and labradorite, with some titanite. (Monzonite, p. 86.)

Hornblende, labradorite and oligoclase. (Labradiorite, p. 67.)

Orthoclase, nepheline, sodalite, and black mica; coarse-grained, (Miascite, p. 63); fine-grained with much blue sodalite. (Ditroite, p. 63.)

Orthoclase, nepheline, zircon, and a little hornblende. (Zircon-syenite, p. 64.)

Orthoclase, red elaeolite, and hornblende. (Foyaite, p. 64.)

Labradorite (compact var. saussurite) and diallage. (Euphotide, part, p. 84.)

Greenish-black hornblende and anorthite. (Corsite, p. 66); if arranged in concentric crystalline rings, alternating with one another. (Orbicular Diorite, p. 67.)

Deep green hornblende, white or gray anorthite and little quartz. (Egeran, p. 110.)

Hypersthene in long black needles, augite, and labradorite. (Teschinite.)

Pyroxene and anorthite. (Eukrite, p. 83.)

Yellow or green chrysolite: decomp. by H_2SO_4; sol. in HCl. (Dunite, p. 111.)

Fine-grained, greenish-gray mass with vitreous feldspar; weathers with a sharply defined white crust. (Phonolite, p. 73.)

b. *Stratified or schistose.*

Fine-grained, greenish-gray mass, showing cleavage surfaces of a vitreous feldspar: weathers with sharply defined white crust. (Phonolite, p. 73.)

Pyroxene, labradorite, viridite; color greenish. (Diabase Schist, p. 82.)

Fine-grained, greenish, hardness 2.5–4. (Chlorite Schist, p. 106.)

Fine-grained, gray or variously colored; hardness 2-3. (Argillaceous mica schist, p. 108.)

c. *Porphyritic.*

States of the rocks described under (a) and (b).

d. *Vescicular and amygdaloidal.*

The dolerite group. Diabase. Phonolite.

Cavities filled with analcite. (Analcimite, p. 81.)

III. COMPLETELY SOLUBLE WITHOUT EFFERVESCENCE.

a. *Massive.*

The iron and manganese ores.

White, hardness 2.5, completely soluble in H_2SO_4, giving HF. (Cryolite.)

IV. MORE OR LESS SOLUBLE WITH EFFERVESCENCE.

a. *Massive.*

The limestones and dolomites, siderite, and travertine.

Greenish felsitic mass with much mica; iron pyrites frequently. (Fraidronite, p. 78.)

Greenish-gray mass with hexagonal tables of mica frequently coated with calcite. (Kersanton, p. 78.)

b. *Stratified or schistose.*

Quartz, mica and more or less calcite. (Calcareous mica-schist, p. 104.)

Calcite and mica. (Cipolino, p. 97.)

Greenish mass, hardness 5, contains calcite. (Kalkaphanite, p. 90.)

INDEX.

ACID crypto-crystalline rocks,53
—— crystalline granular, 49
—— crystalline rocks, 48
—— rocks, 45
—— vitreous rocks, 45
Actinolite, 18
—— schist, 107
Agate, 113
Agglomerated rocks, 3
Albite, 14
Alum schist, 108
Amianthus, 19
Amphibole, 18
Amygdaloidal, 5
Analcite, 38
Analcymite, 38, 81
Anamesite, 80
Andalusite, 36
Andesite, 14, 69, 70
Anhydrite, 99
Anorthite, 14
—— diorite, 66
Anthracite coal, 111
Aphanite, 83, 90
Aplite, 52
Aqueous rocks defined, 44
Arenaceous rocks, 3
Argillaceous group, 94, 108
—— mica schist, 108
Argillaceous rocks, 3
Arkose, 99
Asbestus, 18, 19
Augite-andesite, 71
—— porphyrite, 91
—— syenite, 65

BALL porphyry, 62
Basalt, 87
—— tuff, 101
—— classification of, 87
Basanite, 113
Basic rocks, 45
—— crystalline rocks, 79
—— vitreous rocks, 48
Biotite, 16
Bituminous coal, 111
—— dacite, 71
Black porphyry, 91
—— chalk, 108
Bog-iron ore, 112
Bone breccia, 101
Bone-coal, 112
Breccia, 100
—— bone, 101
—— defined, 3
—— friction, 100
Bronzite, 21
Brown coal, 111

CALAMINE, 113
Calcareous-aphanite, 83, 90.
Calcareous diabase, 83, 91
—— mica schist, 104
—— tufa, 98
Calcite, 24
Cancrinite, 26
Caprolite, 112
Cellular, 5
Chalk, 98
Chiastolite, 36
—— schist, 108
Chlorite, 25
—— gneiss, 106
—— schist, 106
Chlorophoeite, 73
Chrysolite, 30
—— rock, 111
Cipolino, 97
Classification of rocks, 43
Clastic rocks, 3
Clay, 94
Clay slate, 95
Claystone, 94
—— porphyry, 61
Clinkstone, 73
Cleavage, cause of, 4
Coal group, 111
Color, cause of, 7
Composition of rocks, 6
Concretionary, 5
Conglomerate, 100
Conglomerated rocks, 3
Copper slate, 96
Cordierite, 33
—— granite, 52
Corsite, 66
Cryolite, 113
Crypto-clastic, 3
—— crystalline rocks, 69
Crystalline, 2
—— granular, 62
Crystalline rocks, 48
Cyanite, 37
—— rock, 110

DACITE, quartzose, 71
Damourite, 13
—— schist, 104
Definition of the term rock, 1
Delessite, 73
Diabase, 82
—— aphanite, 83
—— schist, 83
Diallage, 19
—— rock, 84
Dichroite, 33
—— gneiss, 102
Diorite, 65
—— and syenite compared, 63
—— porphyrite, 76
Disthene rock, 110
Ditroite, 63
Dolerite, 79
Dolomite, 24, 98
Domite, 55
Dunite, 111

EGERAN, 110
Eklogite, 109
Elaeolite, 26
Elvanite, 60
Enstatite, 20, 113
Epidote, 32
Erlan, 103
Eukrite, 83
Eulisite, 110
Euphotide, 84, 85
Eurite, 58

FELSITE, 58
—— tuff, 101
Feldspar, 11

Feldspar, decomposition of, 13
—— porphyrite, 60
Felsophyre, 6
Felstone, 58
—— porphyry, 61
Fire-clay, 94
Flexible sandstone, 105
Flint, 113
Foyaite, 64
Fracture of rocks, 7
Fragmental, 2
—— rocks, 94
Fraidronite, 78
Friction breccia, 100

GABBRO, 84
Gamsigradite, 19
Garnet, 31
—— rock, 109
Gneiss, 102
—— chloritic, 106
—— dichroite, 102
—— hornblendic, 102
—— protogine, 103
—— syenitic, 102
Globuliferous, 6
Granite, 49
—— origin of, 49–51
—— prophyry, 53
Granitic granite porphyry, 60
Granitite, 52
Granitone, 84
Granophyre, 6
Granular, 2.
—— limestone, 97
Granulite, 103
Graphic-granite, 51, 52
Graphite, 112
Gravel, 99
Greenstone trachyte, 72
—— tuff, 101
Greisen, 53
Grit, 99
Gritty rocks, 3
Groundmass, term defined, 2
Guano group, 112
Gypsum, 98

HALB-GRANIT, 52
Hälleflinta, 59, 103
Hardness of rocks, 7
Haüyne, 26
—— and nosite, 27
—— basalt, 82, 88
—— trachyte, 55
Haüynophyr, 81
Heavy spar, 113
Hematite, 112
Hemitrene, 97
Hornblende, 19, 113
—— andesite, 70
—— porphyrite, 76
—— schist, 107
Hornblendic granite, 50
—— gneiss, 102
Hornstone-porphyry, 61
Hydro-mica schist, 104
Hyperite, 86
Hypersthene, 20
Hypersthenite, 86

ICE, 113
Idocrase, 32
Intermediate rocks, 62
Iolite, 33
Iron Group, 112
—— ores, 112
Itabirite, 105
Itacolumite, 105

JADE, 18
Jasper, 113

KALKAPHANITE, 90
Kaolin, 113
Kersantite, 78
Kersanton, 78
Kinzigite, 110

LABRADIORITE, 67
—— porphyrite, 91
Labrador porphyry, 73
Labradorite, 14
Lepidolite, 16
Lepidomelane, 16
Leucite, 27
—— basalt, 81, 88
—— sanidine, 81
—— tephrite, 88
Leucitophyr, 81
Lherzolite, 110
Lignite, 111
Limestone, 96, 98
—— earthy, 98
—— oolitic, 98
—— shell, 98
Liparite, 57
Lithology, definition of, 1
Loam, 94
Luxullianite, 52

MACLE, 37
Magarodite, 13
Magma, term defined, 2
Magnetite, 112
Manganese ores, 113
Marble, 97
Margarophyllites, 24
Marl, 96
Massive, 51
—— rocks, 43, 102
Melanite, 31
Melaphyre, 73
Metamorphic schists, 102
Metamorphism, 43
Miascite, 63
Micaceous granite-porphyry, 60
Mica, 13
—— basalt, 88
—— calcareous, 104
—— diorite, 67
—— porphyrite, 77
—— quartz-diorite, 68
—— schist, 103
—— trap, 77
Microcline, 14
Millstone-porphyry, 58, 61
Mineral group, 112
Minerals, rock-forming, 9
Minette, 77
Monzoni-hypersthenite, 86
Monzonite, 86
Muscovite, 16

NAPOLEONITE, 67
Nepheline, 26
—— alteration of, into natrolite, 26
—— basalt, 81, 87
—— dolerite, 80
Nephrite, 18
Norite, 85
Normal sedimentary rocks, 94
Nosite, 26
—— and haüyne, 27
—— melanite tephrite, 88
Novaculite, 95

OBSIDIAN, 46
Oligoclase, 14
—— ophite, 71
—— porphyrite, 92
—— trachyte, 55
Olivine, 30
—— andesite, 71
—— gabbro, 86

Omphacite, 22
Oolitic, 6
Opal, 112
Ophicalcite, 97
Ophite, 71
Ophiolite, 97
Orbicular diorite, 67
Orthoclase, 11
Ottrelite schist, 108

PARGASITE, 19
Pearlstone, 46
Peat, 111
Pegmatite, 51
Pargasite, 19
Perlite, 46, 57
—— porphyry, 57
Petrosilex, 58
Phologopite, 16
Phonolite, 73
—— classification of, 73-75
—— tuff, 101
Phyllite, 108
Pisolitic, 6
Pitchstone, 47, 59
—— porphyry, 47
Plagioclase, 12
Plagioclastic feldspars, 12
Plumbago, 112
Plutonic and volcanic rocks, 43, 44
Porfido rosso antico, 76
—— verde antico, 91
Porous, 5
—— porphyry, 61
Porphyritic, 6
Porphyrite, 76
Porphyry, 6
—— tuff, 101
Potstone, 107
Preliminary examination of rocks, 115
Primary rocks, 43, 45
Propylite, 69, 71
Protogine gneiss, 103
—— granite, 51
Puddingstone, 100
Pumice, 46, 48
Pumiceous tuff, 101
Pyrites, 113
Pyromeride, 62
Pyrophyllite, 25
—— schist, 107
Pyroxene, 18, 113
—— syenite, 65

QUARTZ, 10, 113
—— andesite, 71
—— augite andesite, 71
—— diabase, 82
—— diorite, 67
—— porphyry, 60, 61
—— propylite, 72
—— rhyolite, 56
—— schist, 105
—— trachyte, 56
Quartzite, 105
Quartzose dacite, 71

RHOMB porphyry, 76
Rhyolite, 56
Rock salt, 113
Rocks, definition of, 1
—— division of, 43
Rosso antico, 91

SAND, 99
Sandstone, 99
Sanidine, 12
—— oligoclase-trachyte, 55
—— trachyte, 54
Saussurite, 32, 85

Schalstein, 83
Scheme for determining rocks, 115-128
Schistose rocks, 4
Schorl, 36
Scolecite, 38
Secondary rocks, 43
Sedimentary rocks, 43, 93
—— classification of, 93
Semi-anthracite, 112
—— bituminous, 112
Sericite, 13
Serpentine, 25, 109
Shales, 4, 95
Shell limestone, 98
Shingle, 99
Siderite, 112
Sinter, 112
Slates, 4
Slaty porphyry, 61
—— trachyte-porphyry, 58
Smaragdite, 19
—— rock, 109
Sodalite, 26
Spathic iron, 112
Special rocks, 43, 109
Specular iron, 112
Spherulitic structure, 6
Staurolite, 38
Steatite, 25
Striped porphyry, 61
Structure of rocks, 4, 5, 6
Structures in basalt, etc., due to contraction, 89
Syenite, 63
—— and diorite compared, 63
—— porphyry, 60
Syenitic gneiss, 102
—— granite, 51

TACHYLITE, 48
Talc, 22
Talc schist, 107
Tephrite, 88
Textures, 2
Thompsonite, 26
Tonalite, 68
Topaz, 37
—— rock, 106
Tourmaline, 36
—— granite, 52
—— schist, 106
Trachydolerite, 72
Trachyte, 53
—— porphyry, 57
—— tuff, 101
Trachytes, classification of, 54
Trass, 101
Travertine, 98
Tremolite, 18
Tridymite, 54
Tripoli, 113
Tufa, 98
—— calcareous, 98
Tuff, 101
—— basalt, 101
—— felsite, 101
—— greenstone, 101
—— phonolite, 101
—— porphyry, 101
—— pumiceous, 101
—— trachyte, 101

URALITE porphyry, 73

VARIOLITE, 91
Verde antique, 97
Vesuvianite, 32
Vitreous basalt, 48
—— rocks, 45
—— primary rocks, 45